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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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# EVIDENCE OF WHITE SHARK, *CARCHARODON CARCHARIAS,* ATTACKS ON SEA OTTERS, *ENHYDRA LUTRIS*[1]

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**From 1968 through 1979 all verified dead sea otters, *Enhydra lutris,* reported to the California Department of Fish and Game have been recorded and often collected. Approximately 15% of the carcasses exhibited lacerations. Although previous investigators had implicated the white shark, *Carcharodon carcharias,* as a potential predator of sea otters, absolute evidence was meager, and it was believed that most lacerated specimens had been hit by boat propellers. However, since 1974, white shark tooth fragments have been removed from 13 dead sea otters in California (a 14th in the State of Washington) and other indisputable evidence of white shark bites has been found in several additional carcasses. A re-evaluation of previous cause of death determinations ascribed to boat propeller wounds revealed that none of these designations was certain, hence many were changed. Using criteria derived from confirmed shark bitten carcasses, we now speculate that a minimum of 9%, and perhaps 15% or more, of the 657 dead sea otters recorded in California through this period were killed by white shark bites. This mortality has an undetermined effect on California's sea otter population.**

## INTRODUCTION

Since 1968 the California Department of Fish and Game (DFG) has coordinated and participated in a program of dead sea otter verification and examination, and has kept a file of all such records. Some carcasses were given a fairly complete laboratory necropsy; some received only a casual examination in the field. Other badly rotted carcasses or those that were never recovered were not examined. Although a white shark tooth fragment had previously been removed from a lacerated sea otter carcass in California (Orr 1959), a number of investigators initially viewed most of these lacerations to be boat propeller wounds (Morejohn, Ames, and Lewis 1975). By the end of 1976, after white shark tooth fragments had been found in several lacerated sea otter carcasses, we began looking for and finding additional fragments with much greater frequency. At this time we were also able to develop criteria which permitted us to assign with certainty shark bite as the cause of death even when tooth fragments could not be found. These findings prompted a re-evaluation of all previous dead sea otter records particularly to check the evidence of boat propeller wounds.

## REVIEW OF WHITE SHARK ATTACK EVIDENCE

Snow (1910) described hunting of sea otters mainly in the Kurile Islands of

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Russia in the late 1800's and reported that sea otters were bitten by sharks because he had often seen tooth fragments in wounds; he did not specifically mention white sharks. Orr (1959) removed the first verified white shark tooth fragment from a lacerated sea otter found near Carmel, California, in 1958 and speculated that other otters may have died of shark bites. Mattison and Hubbard (1969) necropsied 13 sea otter carcasses but found no lacerating wounds of the type described by Orr. Wild and Ames (1974) reported on 88 carcasses necropsied between January 1968 and July 1973; only one had a laceration pattern which was suspected to have been the result of a shark bite while 22 were thought to have been hit by boat propellers. Morejohn *et al.* (1975) summarized data gathered on all 286 dead sea otters recorded in California between January 1968 and July 1974. They found a white shark tooth fragment in one sea otter carcass (DFG SO-381-73) and indicated that a few other carcasses contained laceration patterns similar to those made by the white shark. The same report attributed 47 deaths to boat propellers; however, an addendum pointed out that the importance of boat propellers had probably been overstated and the importance of shark bites had probably been understated.

In August 1974, a dead sea otter, presumably from a group transplanted from Alaska in 1969–70, was found on a beach on the central coast of Washington. The carcass contained numerous lacerations and a tooth fragment was found (Keyes 1975) which was later identified as that from a white shark.

In January 1975, a sea otter carcass (DFG SO-438-75) was found on a beach at Point Lobos State Reserve, California. The animal was initially thought to have been hit by a boat. Later, B. J. Davis (California State University, San Francisco) found a fragment in a wound which was subsequently identified as an apical portion of a white shark tooth (Figure 1).

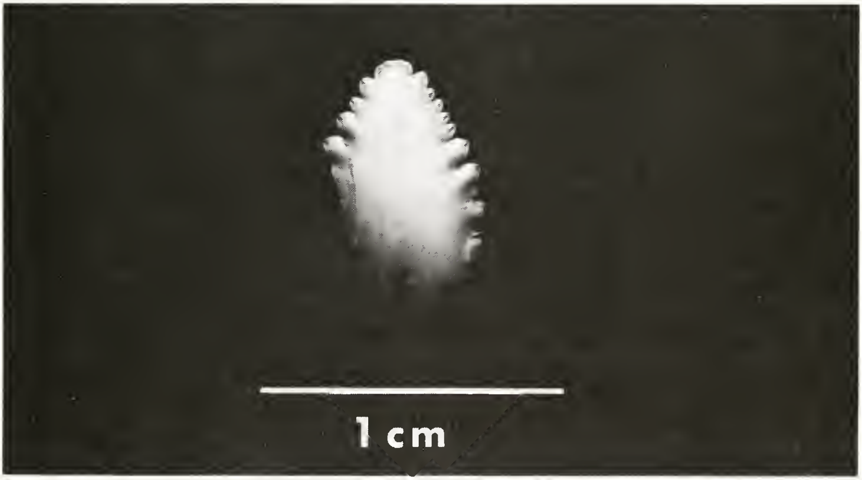


FIGURE 1. Apical fragment of a white shark's tooth recovered from dead sea otter (DFG SO-438-75). *Photo by W. I. Follett.*

On 23 July 1976, a lacerated sea otter was captured alive in the kelp off Monterey, California, by researchers from the University of Minnesota. Some of

the lacerations were sutured by T. D. Williams, consulting veterinarian to DFG. The wounds were suspected to have been inflicted by a knife or boat propeller. Three days later the animal died (DFG SO-509-76) and during the necropsy a white shark tooth fragment was removed from one of the sutured lacerations.

In November 1976, a white shark tooth fragment was removed from a sea otter carcass (DFG SO-529-76) found on the beach near Moss Landing, California, by B. Green Ross (Moss Landing Marine Laboratories).

In May 1977, a sea otter carcass (DFG SO-569-77) exhibiting numerous puncture wounds was found near Pismo Beach, California. This animal was later examined by C. D. Woodhouse, Jr. and P. Collins (Santa Barbara Museum of Natural History), who found, only after careful scrutiny, five white shark tooth fragments.

In August 1977, two lacerated sea otter carcasses were recovered, one (DFG SO-592-77) near Moss Landing (Figure 2) and the other (DFG SO-590-77) near Cambria, California. Many white shark tooth fragments were recovered from both carcasses (Figure 3). One carcass also exhibited a variety of bone scratches and penetrations (Figure 4) and a fragment embedded in the femur near the knee (Figure 5).

FIGURE 2. Lacerated sea otter carcass (DFG SO-592-77) from which several white shark tooth fragments were recovered. *Photo by senior author.*

Also, in August 1977, a white shark tooth fragment was found embedded in the skull of a sea otter (DFG SO-467-75) that had been found (badly decomposed) near Monterey in June 1975 (Figure 6). The cleaned skeleton had been in a museum collection since that time with the shark tooth fragment undetected. This animal is of additional interest in that it was not listed as a carcass suspected of being shark bitten or even as having lacerations.

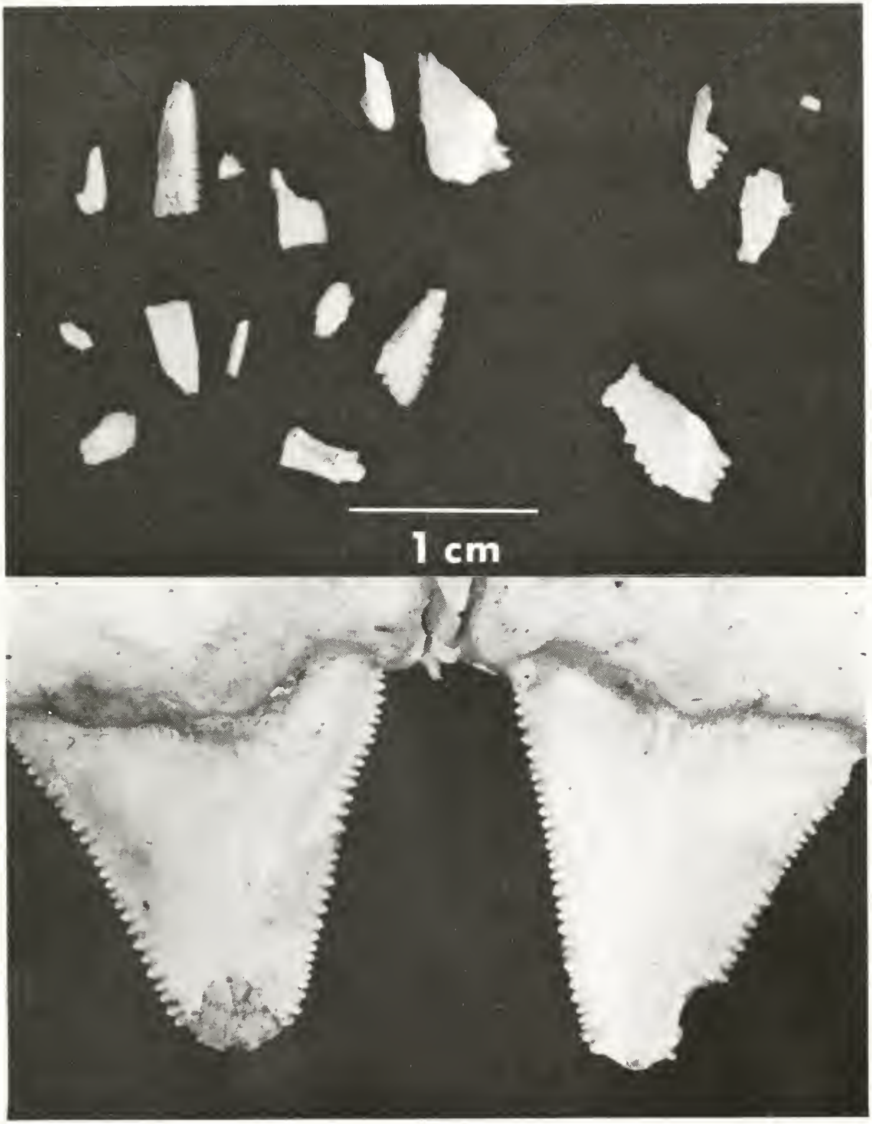


FIGURE 3. Above. White shark tooth fragments removed from dead sea otters. Note how well these fragments might resemble the chips missing from teeth in the photo below. Below. Teeth in the jaw of a white shark caught in Monterey Bay by a fisherman in 1955. *Photo above by senior author. Photo below by J. B. Phillips.*

In November 1977, three small shark tooth fragments were removed from a sea otter carcass (DFG SO-606-77) found on the beach in Monterey.

In 1978 and 1979, shark tooth fragments were removed from four different sea otter carcasses, two from near Carmel (DFG SO-621-78, SO-623-78), one from near San Simeon, California (DFG SO-694-79), and one from near Morro Bay

(DFG SO-718-79). The fragments from two of these carcasses were easily identified as white shark. Fragments from the remaining two were very small (no larger than 3 mm x 3 mm). Although one face of these fragments possessed the pearly sheen typical of shark tooth enamel, they did not possess any or enough of the species diagnostic serrated edge. The fragments were decalcified, sec-

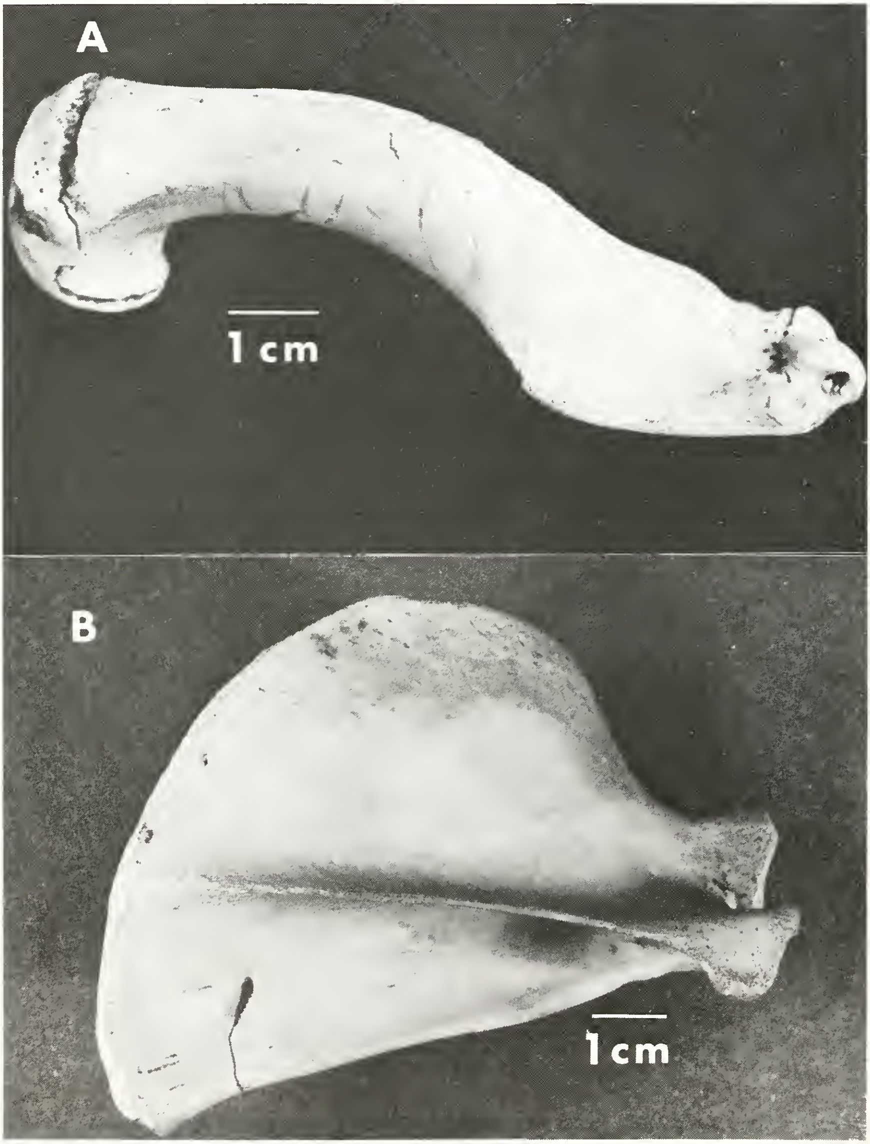


FIGURE 4. (A) Scratched humerus and (B) penetrated scapula from specimen DFG SO-592-77. Scratches or nicks made by white shark tooth serrae are apparent in both. *Photos by senior author.*

tioned and microscopically compared to mammalian bone and tooth enamel, and to white shark tooth enamel by L. T. Pulley (veterinary pathologist). The microscopic appearance was identical to the white shark tooth enamel, however tooth enamel from other shark species was not compared.

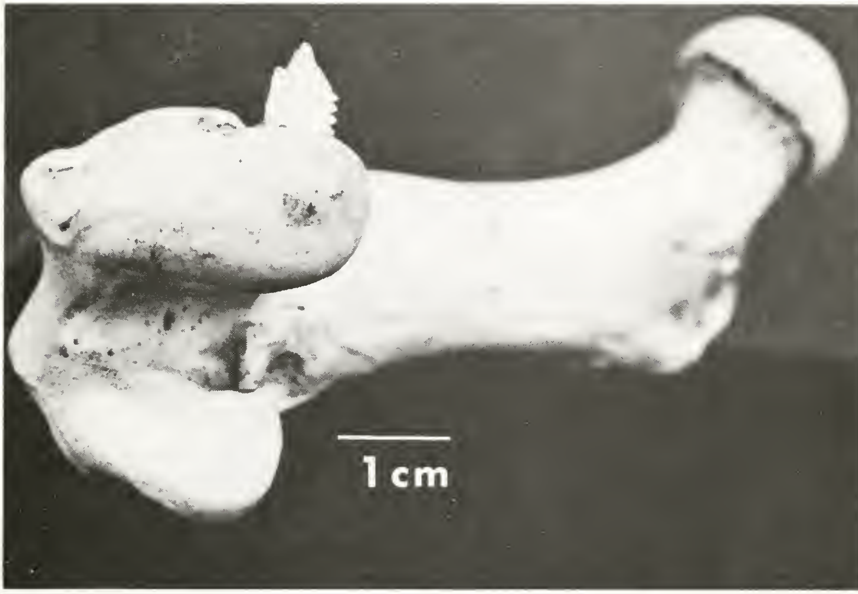


FIGURE 5. White shark tooth fragment embedded in the femur near the knee of specimen DFG SO-592-77. *Photo by senior author.*


FIGURE 6. White shark tooth fragment embedded in the skull of specimen DFG SO-467-75. *Photo by senior author.*

Other virtually indisputable evidence of white shark bites exists. Two sea otters, one from the Morro Bay area and the other from near Monterey (DFG SO-267-72 and SO-455-75), in addition to having multiple cuts in the pelt, had a costal cartilage completely cut. The cut surfaces of these cartilages contained a pattern of grooves matching the serrae of white shark teeth (Figure 7). Two other sea otter carcasses (DFG SO-225-71 and SO-360-73), again, one from near Monterey and the other from near Morro Bay, had stab-like puncture wounds through their skulls in addition to multiple pelt lacerations. In one of these there were scratches matching the serrations of white shark teeth leading to one of the skull penetrations (Figure 8). Other indications of shark bite may be found throughout the dead otter records. The commonest example of these is the "bite-like" series of cuts that have been found in several carcasses (Figure 9).

## BOAT PROPELLER WOUNDS

A DFG biologist approaching Monterey harbor in the 6.5-m research vessel OPHIODON in 1970 observed a sea otter grooming itself a short distance directly in the path of the boat. The speed was reduced, but the otter continued to groom and somersault apparently unaware of the vessel's approach. At very close range the boat was taken out of gear, whereupon it drifted into the startled otter who dived, came up about 3 m away, and then swam off rapidly. The propeller did not strike the otter in this instance, but presumably it could have had the boat been traveling at high speed.

We have documented only one naturally occurring incident in which a boat propeller actually struck a sea otter. In late July 1970, a small salmon boat owned and operated by N. E. Friddle of Pacific Grove, California, and powered by a 65 hp outboard engine accidentally struck a sea otter at full speed just outside Monterey Harbor. The impact damaged the propeller beyond repair. Friddle recalls that blood was abundant in the water around what he presumed was a badly lacerated otter, but his immediate attempts to rescue the animal were unsuccessful. A subsequent attempt by Friddle and a DFG employee to locate the otter was unsuccessful. Two days later, in the same general vicinity, a beached otter was located which had a laceration on the left side of the snout. A week later this animal died (DFG SO-192-70). At the original necropsy, the neck, shoulder, and hindquarters on the left side were noted to have been severely traumatized but only the snout was lacerated. A recent examination of the cleaned skull of this animal revealed no bone damage underlying the snout laceration. Although the dead otter record still lists this carcass as "Friddle's otter," it is very possible that the sea otter he hit was never recovered.

In July 1977, two dead sea otters in fresh condition were intentionally hit by the 7.5-m research vessel ORCA powered by a 250 hp Chrysler marine engine. The boat was traveling at full speed (propeller rotation speed of approximately 1500 rpm's). One of the carcasses (DFG SO-578-77) was totally destroyed and not recovered. The other (DFG SO-577-77) sustained two parallel lacerations both of which were preceded by a distinct shaved area, a condition not previously noted but that could be of diagnostic use (Figure 10).

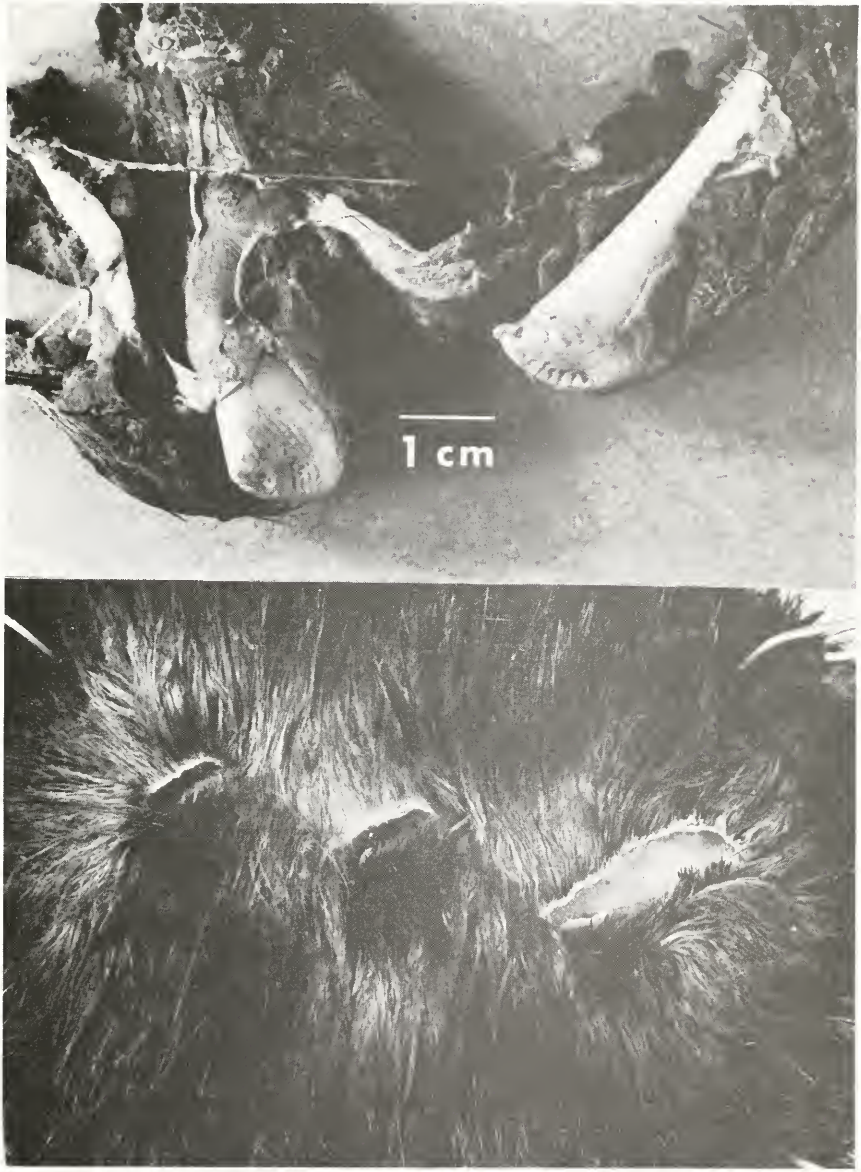


FIGURE 7. Cut costal cartilage (above) from a dead sea otter (DFG SO-455-75) and the overlying piece of pelt (below). The grooved cut surface of the cartilage matches the serrate edge of a white shark's tooth. *Photos by senior author.*

## CRITERIA TO DETERMINE WHITE SHARK WOUNDS AND BOAT PROPELLER WOUNDS

Based upon the wounds found in verified shark bitten sea otter carcasses we

have developed the following criteria which we consider to be diagnostic of white shark bites:

1. Deep stab-like puncture wounds; or very long (superficial or deep) lacerations often associated with smaller cuts; or multiple cuts arranged in a line or arc, often occurring on opposite or various aspects of the carcass.
2. Serrated cut or scratch patterns on or through cartilage or bone; usually associated with 1 above.
3. Shark tooth enamel fragments usually associated with 1 and 2 above. Apparently white sharks often lose tooth fragments in animals they bite since their teeth are composed of a relatively thin brittle enamel shell overlying a softer dentin center. Many of these tooth enamel fragments are very small and may not contain part of the diagnostic serrated edge; however, they will have a "pearly" appearance on at least one surface. Careful scrutiny is required to locate some of these fragments.


FIGURE 8. Skull from a dead sea otter (DFG SO-360-73) exhibiting stab-like punctures. The two scratches leading to the penetration near the center of the skull are diagnostic of white shark tooth serrae. *Photo by Richard McKillop.*

In practice, we now examine all dead sea otters with lacerations for other evidence of shark bite.

Definitive criteria for diagnosing boat propeller wounds do not exist. Our very limited evidence and evidence available from dead manatees, *Trichechus manatus,* suggest that boat propellers make rather large, consecutive, parallel cuts (Figure 11; D. K. Odell, pers. commun.). In heavily furred mammals like sea otters, these cuts may be preceded by a shaved area. Where these cuts extend continuously over hide with and without closely underlying bone, the laceration may appear deeper over the bony area.

FIGURE 9. Series of cuts across the lower back of a dead sea otter (DFG SO-497-76). The spacing of the cuts is suggestive of shark tooth placement. Numerous other lacerations were present on the back, abdomen, feet, and tail of this animal. *Photo by Dan Costa.*

FIGURE 10. A dead sea otter (DFG SO-577-77) subsequently intentionally run over by a boat. Note the two parallel lacerations which are preceded by a distinct shaved area. *Photo by senior author.*

## REEVALUATION OF PREVIOUS CAUSE OF DEATH DIAGNOSES

We have reexamined the dead otter records case by case and, using the criteria set forth above, we now cannot assign a single otter death to a boat

propeller wound with any degree of certainty. We know from Norman Friddle's account that these impacts do happen, but none of the cases reexamined fit our proposed criteria at all well. Many cases, however, did fit the criteria for white shark bites and consequently we changed them. Lacerated carcasses fitting no criteria were listed as "lacerated—cause unknown." Some of these may have resulted from boat propeller impacts and some may have been bitten by white sharks.

FIGURE 11. A dead manatee in Florida with at least ten parallel lacerations on its back, which were probably caused by a boat propeller. *Photo by D. K. Odell.*

## FREQUENCY OF WHITE SHARK ATTACKS

Based upon the portion of the range which is inaccessible to carcass recovery we believe that less than half of the sea otter mortality in California is recorded and we are therefore unable to comment about total mortalilty. However, we now feel that of the 657 carcasses recorded from 1968 through 1979, roughly three-fourths of which were in good enough condition for at least a cursory post mortem examination, a minimum of 60 (9%) were killed by white shark bites. If all of the lacerated carcasses resulted from white shark bites, the number is 100 (15%). If very many of the badly decomposed carcasses (not receiving any post mortem examination) were shark bitten, the percentage could be higher. Finally, if white sharks eat some sea otters, the percentage for total mortality would be higher yet.

## DISCUSSION

Shark bitten sea otter carcasses are recovered from throughout the otters' present range in California although the relative frequency of bites appears to be greater in the northern portion. Seventy-seven percent of the shark bitten carcasses have come from north of Point Sur, California, and 23% to the south. This compares with 57% of all carcasses recorded being from north of Pt. Sur and 43% south (Figure 12).

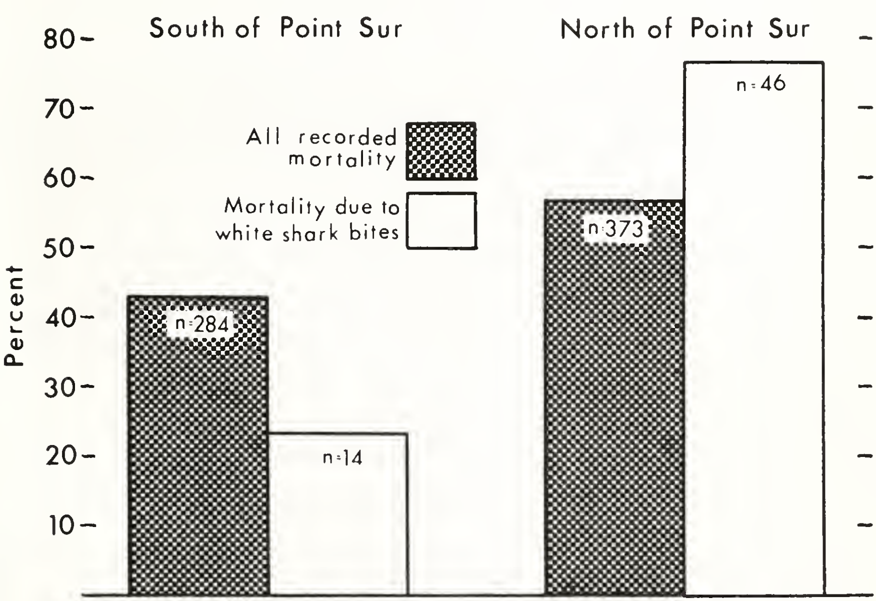


FIGURE 12. Percent of mortality due to white shark bites (and all recorded mortality) that occurred in the southern and northern portions of the sea otters' range in California for the period 1968 through 1979.

For the 1968 through 1979 period, the frequency of white shark bites apparently peaked in 1971 and 1972 (Table 1). However, the paucity of indisputable evidence (tooth fragments) prior to 1976 makes this speculation somewhat tenuous. It is of interest that LeBoeuf, Reidmann, and Keyes (unpubl. data) have documented an increase since the early 1970's in white shark bites on elephant seals, *Mirounga angustirostris,* at Año Nuevo Island and the Farallon Islands.

**TABLE 1. Annual Sea Otter Mortality Due to White Shark Bites from 1968 Through 1979**

| Year | All mortality recorded | Mortality due to white shark bites* No. | % |
|---|---|---|---|
| 1968 | 16 | 1 | 6 |
| 1969 | 36 | 3 | 8 |
| 1970 | 51 | 2 | 4 |
| 1971 | 21 | 7 | 33 |
| 1972 | 46 | 9 | 20 |
| 1973 | 84 | 6 | 7 |
| 1974 | 45 | 6 | 13 |
| 1975 | 52 | 5 | 10 |
| 1976 | 67 | 3 | 4 |
| 1977 | 90 | 7 | 8 |
| 1978 | 82 | 6 | 7 |
| 1979 | 67 | 5 | 7 |
| Totals | 657 | 60 | 9 |

* Includes probable as well as certain cases.

We have recorded shark bitten otters in all months except October, but to date, May and June appear to be the months of highest frequency (Table 2). Sharks appear to attack sea otters of both sexes and all age groups with about the same relative frequency.

**TABLE 2. Sea Otter Mortality Due to White Shark Bites from 1968 Through 1979 by Month**

| Month | All recorded mortality | Mortality due to white shark bites* No. | % |
|---|---|---|---|
| January | 58 | 5 | 9 |
| February | 50 | 4 | 8 |
| March | 86 | 9 | 10 |
| April | 73 | 6 | 8 |
| May | 36 | 7 | 19 |
| June | 71 | 11 | 15 |
| July | 70 | 6 | 9 |
| August | 64 | 4 | 6 |
| September | 48 | 4 | 8 |
| October | 42 ** | 0 | – |
| November | 29 | 2 | 7 |
| December | 30 | 2 | 7 |
| Totals | 657 | 60 | 9 |

* Includes probable as well as certain cases.
** Includes two specimens recovered in the fall of 1969; the month was uncertain.

It is significant that only white shark tooth fragments have been found in dead sea otters. Blue sharks, *Prionace glauca,* and salmon sharks, *Lamna ditropis,* occur throughout the California range of the sea otter, but no fragments of their teeth have been found. Studies of blue shark stomachs from Monterey Bay from 1975 to 1978 produced no evidence of predation on sea otters (Morejohn, Harvey, and Krasnow 1978).

Evidence that white sharks actually prey on sea otters does not exist; i.e., none has been seen consumed, none has been found in a white shark stomach, and no otter carcass has been found with part of the body bitten off. It is obvious that a sea otter could easily be handled by any medium to large white shark. White sharks are known to have eaten far larger mammals. Basically intact harbor seals, *Phoca vitulina,* have been found in white shark stomachs, as have sizable pieces of large elephant seals and other pinnipeds (LeBoeuf *et al.,* unpubl. data). It is conceivable that the lacerated carcasses we are finding represent but a low fraction of the total taken by white sharks. It is equally likely that for some reason white sharks do not eat sea otters and merely bite them and then let them go. In either case, the extent to which this white shark caused mortality may be affecting the Californian sea otter population, if at all, remains to be determined.

## ACKNOWLEDGMENTS

Very many people and institutions have contributed to the data in this report. It would be impossible to name them all but most notable are D. P. Costa, J. J. Geibel, R. A. Hardy, R. E. Jameson, D. B. Lewis, J. E. Mason, J. E. Mattison, Jr., B. Green Ross, J. E. Vandevere, F. E. Wendell, P. W. Wild, T. D. Williams, C. D. Woodhouse, Jr., Moss Landing Marine Laboratories, and Santa Barbara Museum of Natural History. The shark tooth fragment from the State of Washington was identified by C. H. Fiscus (National Marine Fisheries Service) and A. D. Welander (University of Washington). Most shark tooth fragments from California were verified by W. I. Follett, (California Academy of Sciences). L. J. V. Compagno (Stanford University) and D. J. Miller and R. N. Lea (DFG) also examined some tooth fragments. Critical comment on the manuscript was provided by C. D. Woodhouse, Jr., J. E. Estes, J. R. R. Ally, R. N. Lea. D. J. Miller provided major encouragement for the study.

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# RECENT TRENDS IN THE WHITE STURGEON POPULATION IN CALIFORNIA'S SACRAMENTO-SAN JOAQUIN ESTUARY [1]

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**Recent trends in the white sturgeon, *Acipenser transmontanus,* population in the Sacramento-San Joaquin Estuary were evaluated from commercial passenger fishing boat (CPFB) and tagging records. Total catch and catch/angler h on CPFB's declined from 1967 to 1974. Catch/angler h increased from 1974 to 1978, while total catch continued to decrease through 1977. Population estimates suggested that a decrease in abundance occurred between 1967 and 1974 and that abundance increased between 1974 and 1979. Mean size of sturgeon caught on CPFB's increased from 1964 to 1973 or 1974, then decreased through 1978. Annual survival rate changed little over the period examined. The population decline was likely due to poor recruitment from year classes produced after the mid-1950's. Possible causes of low recruitment are discussed.**

## INTRODUCTION

This report analyzes trends in the white sturgeon, *Acipenser transmontanus,* population in the Sacramento-San Joaquin Estuary from 1964 to 1979. This species is a native anadromous fish in the Sacramento-San Joaquin Estuary and is the object of a small but important sport fishery. Another species, the green sturgeon, *A. medirostris,* is much less common and legal-sized ($\geq$ 101.6 cm total length) fish are seldom caught.

Sturgeon are long-lived, late-maturing fish (Roussow 1957; California Department of Fish and Game, unpublished), some living over 50 yr and most maturing at 10 to 15 yr. Fishes with this type of life history normally exhibit long-term population stability and a slow response to environmental vicissitudes (Goodman 1975). Hence, sturgeon populations are vulnerable to overharvest and subsequent decline (Bajkov 1949; Dees 1961) because they cannot rapidly compensate for unusually high mortality.

Historical accounts indicate that a commercial fishery substantially reduced the Sacramento-San Joaquin Estuary white sturgeon population in the late 1800's (Skinner 1962). After a complete fishing closure in 1917, the sport fishery was reopened in 1954. Through 1963 the only catches were generally incidental to the striped bass, *Morone saxatilis,* fishery. Fishing success improved dramatically in 1964 when shrimps, *Crangon* spp. and *Palaemon macrodactylus,* first became popular as bait. Estimated annual harvest rates have been low: at least 2% in 1954 (Chadwick 1959), 7.3% in 1967, 6.5% in 1968 (Miller 1972), and 5.6% in 1974 (Kohlhorst 1979).

Changes in abundance, catch, mean size, and survival may provide clues to factors affecting the sturgeon resource and influence management of the fishery. Over-exploitation is normally characterized by decreasing catch/unit effort and

[1] Accepted for publication May 1980.

declining mean size of fish in the catch (Gulland 1971). Reduced recruitment also causes decreasing catch per unit effort, but mean size increases. The former would suggest that harvest should be restricted, while the latter requires investigation of the causes of poor recruitment. Stable or increasing abundance measurements would suggest a healthy population.

## METHODS

White sturgeon population trends were interpreted from catch, effort, and size data reported by commercial passenger fishing boat (CPFB) operators and from catch/effort, size, and absolute abundance estimated from tagging studies. Since variations in annual survival might have caused fluctuations in abundance, I evaluated survival rates from the only data available. These data provided estimates of survival in 1967 from tag returns and average annual survival over several years from a catch curve.

The CPFB reports were compiled annually from 1964 to 1978 for trips when sturgeon were caught to determine trends in total catch and catch/angler h. Operators of CPFB's are required to furnish the Department with daily logs listing species, number, and sizes of fishes caught, number of anglers, and time spent fishing.

Catch/net h during tagging in San Pablo Bay was available for fall 1967, 1968, 1974, and 1979. This catch/effort index was based on trammel netting in similar areas and months in all 4 yr.

Trends in size of sturgeon were determined from: (i) annual mean lengths and weights calculated from information on logs submitted by the CPFB operators (operators chose to report either length or weight; they seldom reported both), and (ii) mean lengths of white sturgeon tagged in 1967, 1968, 1974, and 1979.

Mark-recapture estimates of legal-size white sturgeon abundance were available from tagging studies in 1954 (Pycha 1956) and 1967 (Miller 1972). Pycha's estimate was derived from a multiple census technique and Miller's was a Petersen estimate. For comparison, I estimated abundance from tagging studies in San Pablo Bay in 1967, 1968, 1974, and 1979 (Miller 1972; Kohlhorst 1979) using the multiple census technique of Shumacher and Eschmeyer (Ricker 1975), where:

$$N = \frac{\Sigma\ (C_t M_t^2)}{\Sigma\ (M_t R_t)}$$

and: $N$ = estimated population
$M_t$ = total tagged fish at large at the start of the $t^{th}$ day
$C_t$ = total fish caught on day t
$R_t$ = number of recaptures in the sample $C_t$.

All the multiple census abundance estimates likely are biased downward as tagged fish probably did not mix randomly with the untagged population during the 2-month tagging season. Sturgeon not in San Pablo Bay were neither subject to tagging nor recapture. Hence, overall, tagged fish would have been more vulnerable to recapture than untagged fish to initial capture. This differential vulnerability, plus effects of immigration to and emigration from San Pablo Bay, make determining the proportion of the entire sturgeon population represented by the abundance estimates impossible. Despite the bias, the abundance esti-

mates probably reflect major trends. However, due to their imprecision, my intent is to present them as supplementary to the other data.

I estimated average annual survival rate from a catch curve (Ricker 1975) using age frequencies of sturgeon collected mostly during tagging in 1974 and on CPFB's in 1973–1976. Aging was as described by Kohlhorst, Miller, and Orsi (1980). The slope of the descending right limb of the curve was estimated using a least squares fit of the linear regression equation: $\log_{10}$ (number of fish) = a + b (age). The $\text{antilog}_{10}$ of the slope (b) is an estimate of survival.

Miller (1972) estimated first year survival of sturgeon using 2 yr of returns from tagging in 1967 and 1968. I re-estimated this survival rate and its confidence interval with 6 yr of returns using a bias-adjusted maximum likelihood equation (Model 1 of Brownie et al. 1978):

$$S_1 = \frac{R_1(T_1-C_1)(N_2+1)}{N_1T_1(R_2+1)}$$

where: $S_1$ = survival rate in 1st yr after 1967 tagging
$R_1$ = total returns from 1967 tagging
$R_2$ = total returns from 1968 tagging
$T_1$ = $R_1$
$C_1$ = returns in 1st recovery year
$N_1$ = number of fish tagged in 1st yr
$N_2$ = number of fish tagged in 2nd yr

Confidence limits for $S_1$ were calculated as $S_1 \pm 1.96SE(S_1)$, where:

$$SE(S_1) = \sqrt{S_1^2\left(\frac{1}{R_1} - \frac{1}{N_1} + \frac{1}{R_2} - \frac{1}{N_2} + \frac{1}{T_2 - R_2} - \frac{1}{T_1}\right)}$$

and $T_2 = R_2 + T_1 - C_1$. The other elements are the same as above.

## RESULTS

### Catch Data

Fishing success declined during much of the period examined. Sturgeon catch reported by CPFB's declined from a peak of 2,272 fish in 1967 to a low of 327 fish in 1977 (Figure 1). Catch/angler h on CPFB's decreased from 0.052 in 1964 to 0.028 in 1974 and then increased to 0.039 in 1978 (Figure 1). Negative linear trend lines for both catch (1967–1978) and catch/angler h (1964–1974) were significantly different from zero ($p < 0.0005$). The positive trend in catch/angler h from 1974 to 1978 was not significantly different from zero ($p \cong 0.10$).

Legal-sized white sturgeon also were more difficult to catch with trammel nets in San Pablo Bay in 1974 than in 1967, 1968, or 1979. Catch/net h during tagging was 15.3 in 1967, 19.5 in 1968, 3.7 in 1974, and 8.4 in 1979. Hence, catch rate in 1974 was 79% lower than the 1967–1968 mean and 56% lower than in 1979.

Mean length of sturgeon reported by CPFB's increased from 124 cm in 1964 to 134 cm in 1974 (Figure 2). Sample sizes were too small from 1975 to 1978 (only 1 to 11 fish) to calculate reliable mean lengths. Mean weight increased from 13.8 kg in 1964 to 19.0 kg in 1973 and then decreased to 14.9 kg in 1978. Positive linear regression slopes of trends in both mean length from 1964 to 1974 and mean weight from 1964 to 1973 were significantly different from zero

($p<0.0005$). The negative trend in mean weight from 1973 to 1978 was also statistically significant ($p<0.0005$).

The mean length of sturgeon captured for tagging also increased from the late 1960's to 1974, then declined substantially between 1974 and 1979 (Figure 2).

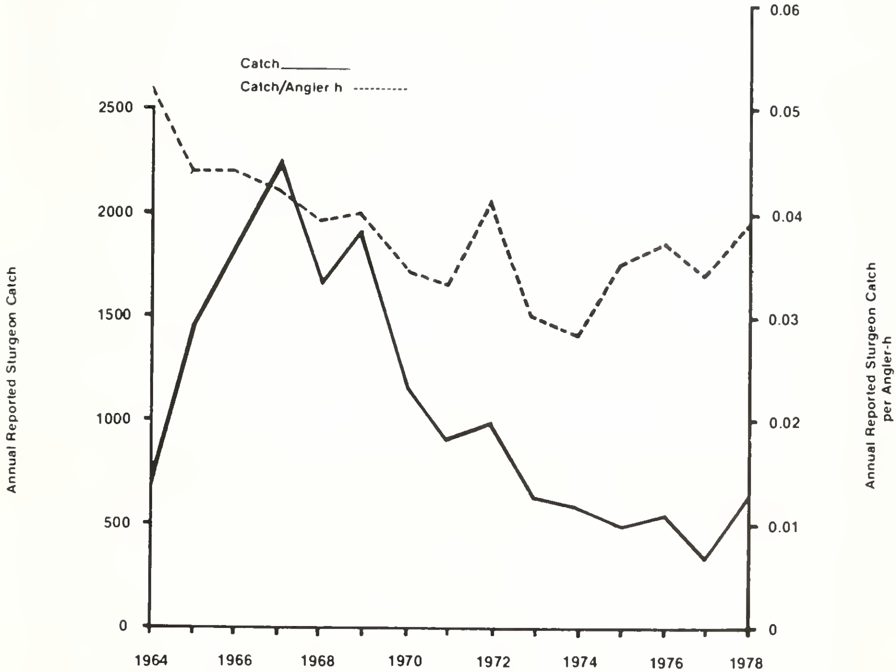


FIGURE 1. Annual reported sturgeon catch and catch/angler h by commercial passenger fishing boats in the Sacramento-San Joaquin Estuary.

## Mark-Recapture Estimates

From 1967 to 1974, trends in the mark-recapture abundance estimates (Table 1) were about the same as those demonstrated by the CPFB and netting data. Specifically, the estimate for 1974 was lower than those for 1967 and 1968 and the estimate for 1979 suggested abundance increased after 1974. My 1967 estimate was similar to Miller's (1972) for the same year, but a major inconsistency is that the estimate for 1968 is lower relative to 1967 and 1979 than would be expected from the other data. Presumably, this reflects the previously mentioned imprecision in the multiple census data. The 1954 estimate is lower than any of the more recent estimates suggesting abundance was relatively low then.

## Survival Estimates

The slope of the righthand limb (age 9–20) of the catch curve for white sturgeon collected in 1973–1976 was $-0.0569$ (Figure 3). Estimated mean annual survival (antilog $_{10}$ $-0.0569$) was 0.878 (95% CI $=$ 0.818, 0.941). The scatter and moderate nonlinearity of points in the righthand limb suggest that survival and/or recruitment were variable over the 12-yr period represented by those ages.

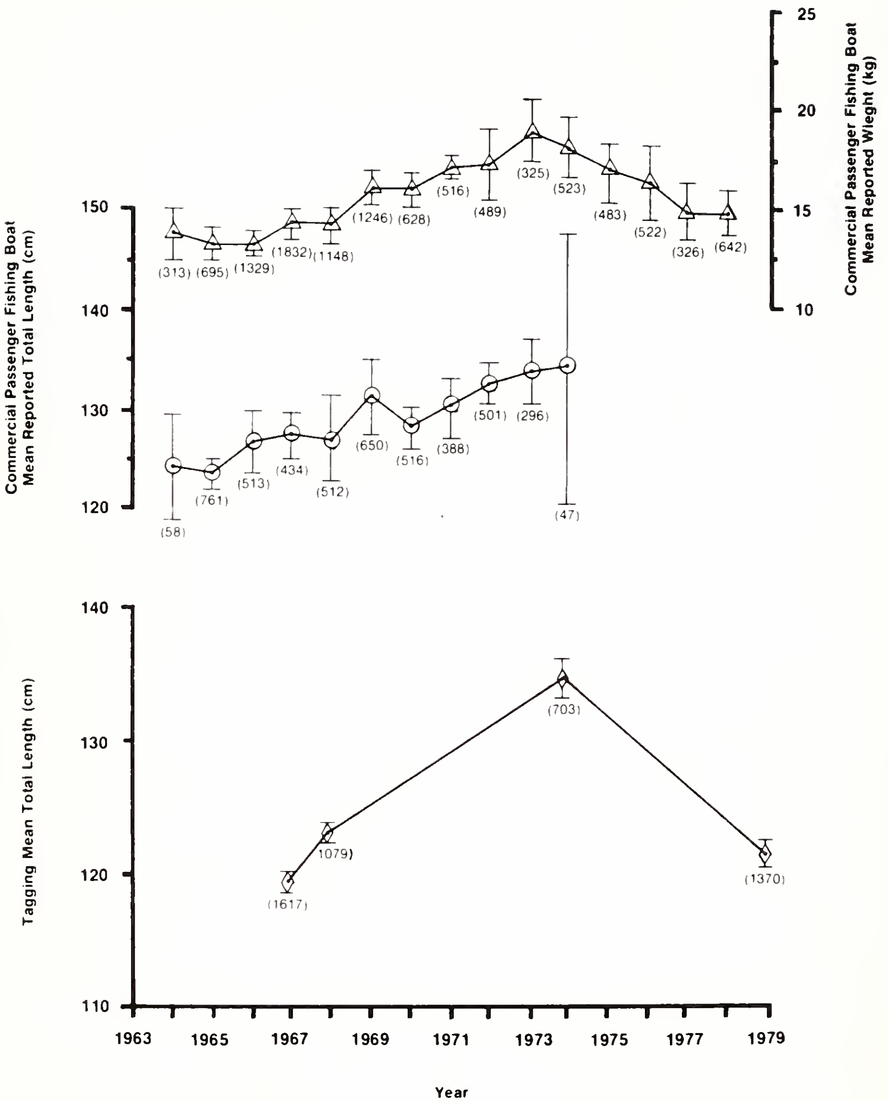


FIGURE 2. Annual mean weight and total length reported by commercial passenger fishing boats and mean total length during tagging of sturgeon in the Sacramento-San Joaquin Estuary. Bars are 95% confidence intervals and numbers in parentheses are sample sizes.

Six years of returns from tagging in 1967–1968 (Table 2) yielded an estimated survival rate of 0.841 (95% CI = 0.648, 1.03) for the first year after tagging in 1967. The similarity of these two estimates suggests that changes in survival rate were not large enough to cause the observed fluctuations in abundance.

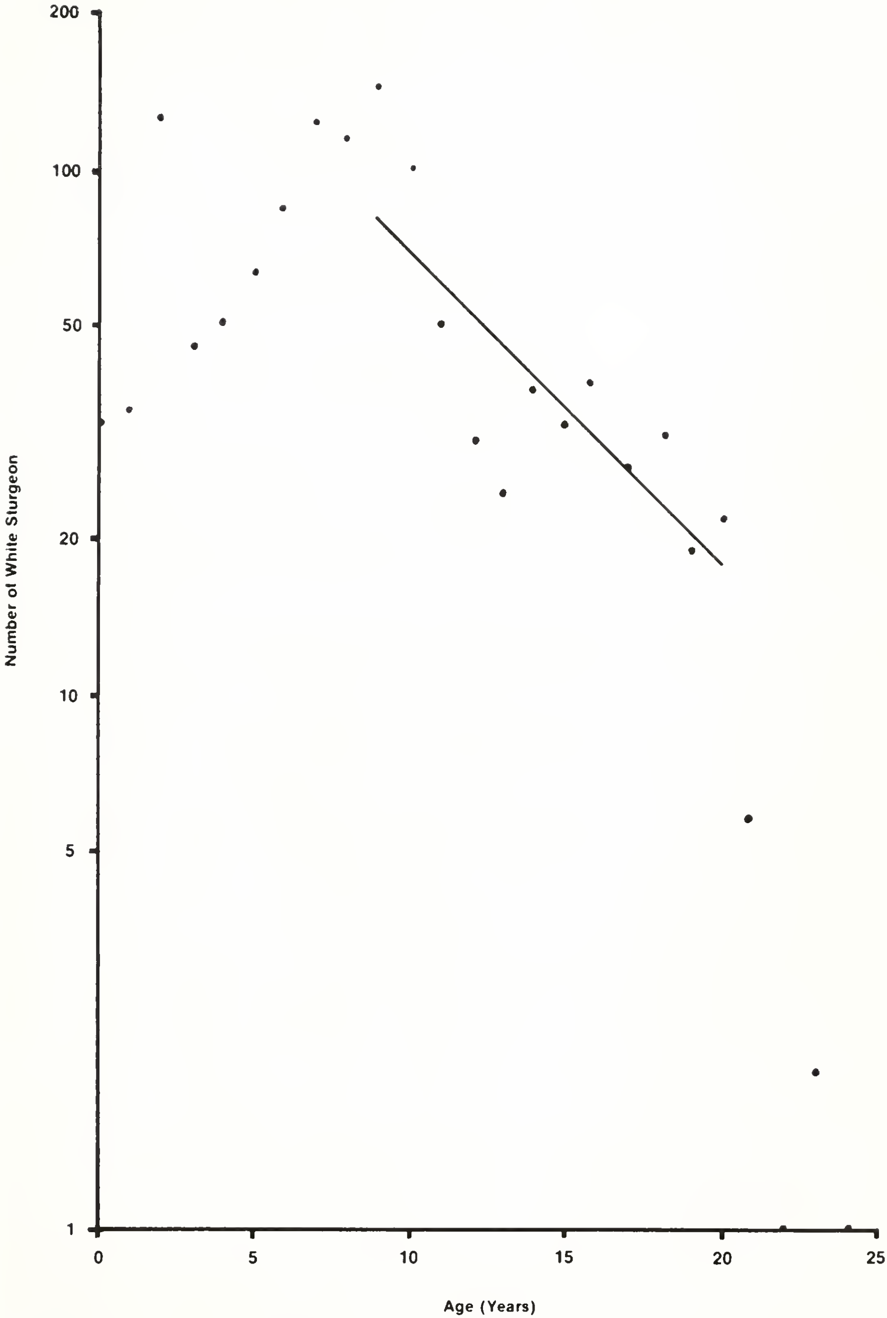


FIGURE 3. Catch curve of white sturgeon collected from 1973 to 1976 in the Sacramento-San Joaquin Estuary. Annual survival of 0.878 for age 9–20 fish was estimated from the antilog$_{10}$ of the slope ($-0.0569$) of the line.

**TABLE 1. Population Estimates for Legal-Sized ($\geq$ 101.6 cm TL) White Sturgeon in the Sacramento-San Joaquin Estuary. Numbers in Parentheses Are the Number of Recaptures on Which the Estimates Are Based.**

| *Year* | *Population estimate* |
|---|---|
| 1954 | 11,154 (45) [1] |
| 1967 | 114,667 (14) [2] |
| | 110,500 (10) |
| 1968 | 40,000 (12) |
| 1974 | 20,700 (12) |
| 1979 | 74,500 (13) |

[1] Pycha 1956
[2] Miller 1972

**TABLE 2. Six Years of Tag Return Data from 1967 and 1968 White Sturgeon Tagging in the Sacramento-San Joaquin Estuary Used to Estimate Survival in the First Year After 1967 Tagging.**

| *Year tagged* | *Number tagged* | *Year of recovery* 1 | 2 | 3 | 4 | 5 | 6 | *Total recoveries* |
|---|---|---|---|---|---|---|---|---|
| 1967 | 1,212 | 87 | 73 | 34 | 18 | 11 | 7 | 230 |
| 1968 | 819 | | 53 | 22 | 14 | 14 | 11 | 114 |

## DISCUSSION

My analysis of trends in the sturgeon fishery depends greatly on unsupervised reporting by CPFB operators. The long-term reliability of sturgeon CPFB logs is unknown, but striped bass logs do adequately reflect catch trends in that fishery (Grant 1977), and sturgeon size and catch trends developed from the log data agree reasonably well with trends apparent from our own measurements suggesting that the log data are adequate for my purpose.

Trends in catch/effort during tagging and by CPFBs, total CPFB catch, and population estimates all indicate that white sturgeon abundance declined in the Sacramento-San Joaquin Estuary between 1967 and 1974, and, possibly, since at least 1964. After 1974, CPFB reports and the 1979 population estimate suggest that abundance increased.

Mean size increased as abundance decreased, suggesting that the population decline between 1967 and 1974 was not due to overexploitation. Reductions in fish populations due to exploitation are normally accompanied by decreases in mean size of fish in the catch (Gulland 1971), assuming growth does not increase concurrently.

The survival rate apparently changed little and exploitation was low during the period examined. Annual survival of 84–88% and harvest rates of 6–7% intuitively appear adequate to maintain a stable population.

Hence, the trends in abundance and size most likely resulted from low recruitment from 1967 to 1974. Since white sturgeon reach legal size at age 6–12 (Kohlhorst, Miller, and Orsi 1980), the weak year classes would have to be produced starting as early as the mid-1950's or as late as the early 1960's.

The three most likely causes of poor recruitment are: (i) Degradation of juvenile habitat. Survival of juveniles of other anadromous species in the Sacramento-San Joaquin System, such as striped bass, American shad, *Alosa sapidissima,* chinook salmon, *Oncorhynchus tshawytscha,* and longfin smelt,

*Spirinchus thaleichthys,* is reduced by low freshwater flows and high water diversion rates during the spawning and nursery periods (Turner and Chadwick 1972; Chadwick, Stevens, and Miller 1977; Stevens and Miller, unpubl. data). Low freshwater flows apparently impact juveniles of these species by restricting available habitat or reducing food supplies. Water diversions reduce survival by directly removing fish or by changing flow patterns to disrupt migrations.

Freshwater outflow from the Sacramento-San Joaquin Delta in late spring and summer, the period that might be critical for sturgeon, was low from 1959 to 1962 and in alternate years thereafter through 1972. During this period, flows were highest in 1967 and 1969. Also, the percent of inflow diverted from the Delta increased substantially after 1958. For example, the mean percent of May–June inflow diverted was 5.1% from 1951 to 1958 and 19.7% from 1959 to 1968. Since sturgeon are recruited between ages 6 and 12 (Kohlhorst, Miller, and Orsi 1980), flow and/or diversion conditions during a period as brief as 1959–1962 could have depressed recruitment from 1965 to 1974, while high flows in 1967 and 1969 may explain increased abundance since 1974. As partial corroboration of the latter, the 1969 year class comprised 19.1% of the sturgeon tagged in 1979 and was the most abundant age group in the sample. However, the next most abundant year class was from 1970 (17.6%), a relatively low flow year.

The effect of flow on recruitment also may be reflected in Pycha's (1956) data which suggested that dominant year classes were produced in 1938 and 1948. Late spring and early summer flows were high in both of those years, particularly in 1938.

(ii) Environmental contaminants. Polychlorinated biphenyls (PCB's) are of special concern. Samples of legal-sized sturgeon collected in San Pablo and Suisun bays in 1975 contained mean gonadal PCB concentrations of (mean ± SD) 49.3 ± 24.8 ppm in males and 23.7 ± 27.8 ppm in females (California Department of Fish and Game, unpublished). A concentration of 7.0 ppm of PCB in eggs of the sheepshead minnow, *Cyprinodon variegatus,* caused mortality in the fry (Hansen, Schimmel, and Forester 1974). Hogan and Brauhn (1975) found that 60–70% of rainbow trout, *Salmo gairdneri,* fry were deformed 30 d after hatching due to PCB levels of 2.7 ppm in the eggs. Mortalities were also increased by PCB's in the first 30 d after hatching.

These studies suggest that PCB's may reduce survival of larval sturgeon and subsequent recruitment. They gained wide use in late 1930's and early 1940's (Walker 1976), so sturgeon probably have been accumulating them for many years. Unfortunately, long term information on PCB concentrations in white sturgeon is not available to indicate whether PCB's actually could account for recent changes in sturgeon abundance.

(iii) Spawning stock size. Declining abundance of sturgeon between 1967 and 1974 and the apparent increase thereafter may be caused by fluctuations in abundance of mature spawners. Preliminary analysis of age composition data collected in 1954, 1965–1970, and 1973–1976 suggests that, since 1932, there has been about a 14-yr periodicity in year class strength. Fourteen years is approximately the age of first spawning of female white sturgeon (California Department of Fish and Game, unpublished). Perhaps, strong year classes produce large numbers of young when they mature and weak year classes, few young.

However, all females from a year class do not mature at the same time and many live long enough to spawn more than once. These older fish have higher fecundity than first-time spawners. These facts suggest the explanation is more complicated than a simple 14-yr cycle.

Exploration of factors possibly affecting sturgeon recruitment is continuing. If recruitment is affected by controllable factors, these could be manipulated to increase sturgeon abundance.

## ACKNOWLEDGMENTS

I wish to thank D. Ramczyk for first bringing to my attention the decline in catch and increase in size of white sturgeon reported by CPFB's. Many other Department employees assisted me in both the field and laboratory. D. Stevens and H. Chadwick critically reviewed the manuscript. A. Conner drafted the figures. This work was performed as part of Dingell-Johnson Project California F-9-R, "A Study of Sturgeon, Striped Bass, and Resident Fishes", supported by Federal Aid to Fish Restoration funds.

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*Calif. Fish and Game* 66(4): 220–232

# AN ANNOTATED CHECKLIST OF FISHES FROM HUMBOLDT BAY, CALIFORNIA [1]

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**Records of fishes occurring in Humboldt Bay have been kept since the mid-1950's in order to determine the Bay's importance as a nursery or spawning area, feeding area, or residence for the various sport and commercial fishes of California's north coast. Occurrences were obtained from published and unpublished reports. Various methods were used to collect the fishes, including traps, trawls, hook-and-line, beach seines, and collections at a power plant's intake screens.**

**To date, 110 species have been recorded from the Bay. The study indicates that the Bay plays an important role in the life history of several important sport and commercial fishes including: *Clupea harengus,* (spawning); *Embiotoca lateralis,* (resident); *Hexagrammos decagrammus,* (nursery); *Ophiodon elongatus,* (nursery); *Parophrys vetulus,* (nursery); *Oncorhynchus kisutch* and *O. tshawytscha,* (feeding); and *Sebastes caurinus,* (nursery).**

## INTRODUCTION

Humboldt Bay is one of the largest natural bays in California, comprising 17,000 acres of open water, tidal flats, and marshes. Bay waters function as habitat, a food source, breeding ground, nursery area, and migratory route for a host of marine animals. Man has used the Bay for over 100 years as a deep-water port, food source, log dump, dumping ground for sewage and other waste, recreational area and for land development. These activities affect the ability of the Bay to continue in its historical biological function. Fishes comprise the major portion of the Bay's fauna, both in number of species and in biomass. Many are important to the Bay's sport fishery and small commercial fisheries; others, which use the Bay as a nursery area, contribute to commercial and sport fisheries outside the Bay.

During the 1950's, California Department of Fish and Game (DFG) biologists began compiling species lists to obtain a more complete understanding of the Bay's role in the ecology of north coast fishes. The checklist presented here combines data from sport fishing creel censuses, research trawling, larval fish studies, fish collections from trash racks in water intake screens, and other sources.

## MATERIALS AND METHODS

Species occurrences were obtained from the following sources: Allen, Delacy,

[1] Accepted for publication June 1980.

and Gotshall (1960); Miller and Gotshall (1965); Gotshall (1966); Gotshall and Fitch (1968); Allen, Boydstun, and Garcia (1970); Dewees (1970); DeGeorges (1972); Eldridge and Bryan (1972); Prince (1972); Stein (1972); Samuelson (1973); Sopher (1974); Quirollo and Dinnel (1975); unpublished Department of Fish and Game monthly trawl data; unpublished Humboldt State University trawl data; monthly collection of fishes at trash screens at coolant water intakes at the Pacific Gas and Electric Company (PG&E) Buhne Point Power Plant; beach seining by commercial fishermen; and validated, unpublished records. The designation of the Bay's function in the life history of each species is based on our observations over the years and is subject to future revision. Families are listed alphabetically under each of the two major classes of fishes, the cartilaginous fishes and the bony fishes. Lengths are total lengths in centimetres (cm) unless otherwise noted. Maximum size was not available for all Humboldt Bay species. Data from Miller and Lea (1976) were used to determine new size records.

## RESULTS

The list contains 110 species belonging to 43 families (Appendix 1). Forty-four species are known or probable residents. At least six species are known to spawn in the Bay, based on the presence of eggs and/or larvae and capture of adults during the spawning season. Probably the most important spawner is the Pacific herring, *Clupea harengus*. The Bay functions as a nursery area for at least seven species including the English sole, *Parophrys vetulus,* an important component of the commercial trawl catch outside Humboldt Bay. Our observations also indicate that 16 species enter the Bay to feed, the most important of this group are the coho and chinook salmon, *Oncorhynchus kisutch* and *O. tshawytscha.* Thirty-five species are infrequently or rarely captured in the Bay and are considered as occasional or chance visitors.

A total of 45 species has been caught by sport fishermen in the Bay and 9 species have been commercially fished.

## DISCUSSION

We realize that the list is not complete. Any fish inhabiting the eastern north Pacific ocean outside the Bay could be expected in the Bay on occasion. Additional species also will be recorded in the future, as different collecting techniques are employed. Many species that we had expected to appear in collection records for the Bay were missing. For example, the gopher rockfish, *Sebastes carnatus,* and black-and-yellow rockfish, *Sebastes chrysomelas,* which reportedly range north to Eureka, to our knowledge have not been observed or captured in Humboldt Bay or around the entrance jetties.

It is clear that Humboldt Bay is an important habitat for many species of fishes; therefore, any project that would threaten the Bay's ability to function as a nursery, feeding, spawning area, or permanent residence should be very carefully considered.

## ACKNOWLEDGMENTS

This checklist is the result of contributions of time and data from a great many individuals. Space limitations force us to list only a few of those who have contributed over the years. Department of Fish and Game biologists E. Best, E.

Gibbs (deceased), and T. Jow were responsible for compiling the original checklist. J. E. Fitch confirmed many of the identifications. T. Sopher provided data from his trawl study in Arcata Bay; P. Dinnel supplied the data from the PG&E screens; E. Herald (deceased), R. Stein, L. B. Boydstun, J. Hanlon, J. Turk, and "Jake" Houck provided individual species records; N. Nelson, S. Taylor, M. Willis, R. Hardy, J. Spann, D. Cross, and L. Murakami assisted in the Department's Humboldt Bay trawl study. R. N. Lea and J. E. Fitch edited the original manuscript. R. N. Lea also provided taxonomic and nomenclatural assistance. To all of these individuals and the host of Humboldt State University students and sport and commercial fishermen who also provided records or participated in individual projects, we offer our sincere thanks.

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## APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]

| Species | Common name | Season of occurrence[2] | Habitat[3] | Capture method[4] | Bay maximum size (cm) | Bay function[5] | Remarks |
|---|---|---|---|---|---|---|---|
| Family Carcharhinidae | | | | | | | |
| *Galeorhinus zyopterus* | soupfin shark | * | | SF | | OV | * One record; P. Dinnel, Univ. of Washington, pers. commun. |
| *Mustelus henlei* | brown smoothhound | SP, S, F, W | MF, C, AF | SF, RT, PG&E | 93 | R | |
| *Triakis semifasciata* | leopard shark | SP, S, F, W | MF, C, P | SF, RT, PG&E | | R | |
| Family Chimaeridae | | | | | | | |
| *Hydrolagus colliei* | ratfish | * | C | DN | | OV | * One record; J. Houck, Humboldt State Univ., pers. commun. |
| Family Dasyatidae | | | | | | | |
| *Urolophus halleri* | round stingray | * | C | BS | | OV | * One record; a 408-mm male (Best 1961). |
| Family Hexanchidae | | | | | | | |
| *Notorynchus maculatus* | sevengill shark | SP, S, F | C | SF, CF* | 14.9 kg** | R | * Supported commercial fishery during the late 1800's and early 1900's. **Size record; E. Herald, Calif. Academy of Sciences, pers. commun. |
| Family Myliobatidae | | | | | | | |
| *Myliobatis californica* | bat ray | SP, S, F | C, MF, P | SF, RT, PG&E, T, BS | 136 | F, N, S | |

[1] Common and scientific names follow American Fisheries Society Special Publication No. 6. (1980) and Miller and Lea (1976).
[2] Season of occurrence: SP—spring, S—summer, F—fall, W—winter.
[3] Habitat: C—channels, MF—mud flats, P—piers, J—jetties, AR—artificial reefs.
[4] Capture method: LF—larval fish studies, SF—sport fishery, CF—commercial fishery, RT—research trawl, PG&E—Pacific Gas and Electric Company power plant trash screens, T—traps, BS—beach seine, Scuba, DN—dip net.
[5] Bay function: In most cases these are subjective evaluations based on our observations over the years. R—residence, F—feeding area, S—spawning area, M—migratory route, N—nursery area, OV—occasional visitor.

**APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]—Continued**

| *Species* | *Common name* | *Season of occurrence* [2] | *Habitat* [3] | *Capture method* [4] | *Bay maximum size (cm)* | *Bay function* [5] | *Remarks* |
|---|---|---|---|---|---|---|---|
| Family Rajidae | | | | | | | |
| *Raja binoculata* | big skate | SP, S | C, P | SF, RT, PG&E | 65 | OV | |
| Family Squalidae | | | | | | | |
| *Squalus acanthias* | spiny dogfish | | C | SF | | OV | |
| Family Acipenseridae | | | | | | | |
| *Acipenser medirostris* | green sturgeon | S, F, W | C | SF, RT | 112 | R | |
| Family Agonidae | | | | | | | |
| *Odontopyxis trispinosa* | pygmy poacher | * | C | LF, RT | 7.4 | OV | * Juveniles collected in December; Eldridge and Bryan (1972). |
| *Pallasina barbata* | tubenose poacher | | C | RT | 15* | | * Apparently a new record size; Miller and Lea (1976) give the size as 13.5 cm. |
| *Stellerina xyosterna* | pricklebreast poacher | S, F, W | C | LF*, RT, PG&E | 10.8 | OV | * Larvae and juveniles occurred in Eldridge and Bryan's (1972) studies in June, July, and October. |
| Family Ammodytidae | | | | | | | |
| *Ammodytes hexapterus* | Pacific sand lance | SP, S, F, W | C | RT | 11 | R | Important food for chinook and coho salmon at certain times. |
| Family Anarhichadidae | | | | | | | |
| *Anarrhichthys ocellatus* | wolf-eel | * | J, AF | SF | | R | * Probable resident, but uncommonly captured by sport fishermen. |
| Family Atherinidae | | | | | | | |
| *Atherinops affinis* | topsmelt | SP, S, F, W | C | PG&E | 23 | R | |
| *Atherinopsis californiensis* | jacksmelt | SP, S | C, P, J | LF*, SF, PG&E | 42 | F | * Larvae collected only in April and June; Eldridge and Bryan (1972). Second most frequently caught fish by pier fisherman in Bay (Miller and Gotshall 1965). |
| Family Bothidae | | | | | | | |
| *Citharichthys sordidus* | Pacific sanddab | SP, S, F, W | C, MF | RT, PG&E, BS | 17.4 | OV | Of minor commercial importance to trawl fisheries outside of Bay. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Citharichthys stigmaeus* | speckled sanddab | SP, S, F, W | C, MF, AF | RT, LF*, PG&E, T, BS | 19.2** | R | *Larvae collected only in December (Eldridge and Bryan 1972). **New record; Miller and Lea (1976) list 17.0 cm as the size record. |
| *Paralichthys californicus* | California halibut | * | C | RT | 33 | OV | * Less than a dozen have been recorded from the Bay. |
| Family Centrolophidae | | | | | | | |
| *Icichthys lockingtoni* | medusafish | * | C | RT | | OV | * One fish captured in trawl September 1968. |
| Family Clupeidae | | | | | | | |
| *Alosa sapidissima* | American shad | | C, MF | BS | | OV | |
| *Clupea harengus* | Pacific herring | SP, S, F, W | C, MF, P | LF, CF, RT, PG&E, BS | 27.0 | S | Larvae present from January through May (Eldridge and Bryan 1972). |
| *Dorosoma petenense* | threadfin shad | * | C | RT, PG&E | 12.5 | OV | * Only three have been recorded from Bay. |
| Family Cottidae | | | | | | | |
| *Artedius fenestralis* | padded sculpin | W, SP, S, F | C, P, J | RT, PG&E, T | 14.2* | R | * Exceeds size record for species given by Miller and Lea (1976). |
| *Artedius harringtoni* | scalyhead sculpin | SP | C | PG&E | 11.2* | R | * New size record; previous record was 10.2 cm (Miller and Lea 1976). |
| *Artedius notospilotus* | bonehead sculpin | * | C | RT | | | * One record from Bay; T. Jow, DFG field notes. |
| Ascelichthys rhodorus | rosylip sculpin | W, SP | C, J | SF, RT, PG&E | 16.8* | R | * New size record; previous record was 15.0 cm (Miller and Lea 1976). |
| *Blepsias cirrhosus* | silverspotted sculpin | * | C | RT | 10.2 | OV | * One record from Bay. |
| *Clinocottus acuticeps* | sharpnose sculpin | * | tide pool | DN | | | * One record from Bay; six specimens collected by R. Sein, Humboldt State Univ. (pers. commun.). |
| *Cottus aleuticus* | coastrange sculpin | W | FW | RT | 7.5 | | One record; probably washed into Bay from tributary streams during heavy rains. |
| *Cottus asper* | prickly sculpin | W | FW | PG&E | 16.0 | | Another freshwater sculpin that occasionally is washed into Bay during heavy rains. |
| *Enophrys bison* | buffalo sculpin | SP, S, F, W | C, P, J, AR | SF, RT, PG&E, T | 24.5 | R | |

**APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]—Continued**

| Species | Common name | Season of occurrence [2] | Habitat [3] | Capture method [4] | Bay maximum size (cm) | Bay function [5] | Remarks |
|---|---|---|---|---|---|---|---|
| *Hemilepidotus hemilepidotus* | red Irish lord | SP, S, F, W | C, J | SF, RT, PG&E | 16.0 | R | |
| *Hemilepidotus spinosus* | brown Irish lord | SP, S, F, W | C, J, AR | SF, RT, T | 17.7 | R | |
| *Leptocottus armatus* | Pacific staghorn sculpin | SP, S, F, W | C, P, J, AR | SF, RT, PG&E, T | 28.0 | R | |
| *Nautichthys oculofasciatus* | sailfin sculpin | SP | C, J | RT, PG&E | | R | |
| *Oligocottus snyderi* | fluffy sculpin | * | tide pool | DN | | | * R. Stein, Humboldt State Univ. (pers. commun.) reported capture of two juveniles in a tide pool. |
| *Scorpaenichthys marmoratus* | cabezon | SP, S, F, W | C, J, P, AR | SF, RT, PG&E, T | 32.0 | R | Important Bay sport fish, particularly around jetties. |
| Family Cryptacanthodidae | | | | | | | |
| *Delolepis gigantea* | giant wrymouth | * | C | PG&E | | OV | * On 13 February 1969, a single fish was recorded from the PG&E screens (J. Houck, Humboldt State Univ., pers. commun.). |
| Family Cynoglossidae | | | | | | | |
| *Symphurus atricauda* | California tonguefish | F, W | C | RT, PG&E | 8.8 | OV | |
| Family Embiotocidae | | | | | | | |
| *Amphistichus koelzi* | calico surfperch | W, SP, S | C, J | SF | | F | |
| *Amphistichus rhodoterus* | redtail surfperch | W, SP, S | C, P, J | SF, CF, RT, BS | 36.0 | F | Ranked third in importance in Bay surfperch sport catch during 1957–1960 survey (Miller and Gotshall 1965). |
| *Cymatogaster aggregata* | shiner surfperch | SP, S, F, W | C, P, J, AR | SF, RT, PG&E, T | 19.2* | R | * New size record, previous record was 17.8 cm (Miller and Lea 1976). Ranked second in importance in Bay surfperch sport catch during 1957–1960 survey (Miller and Gotshall 1965). |
| *Damalichthys vacca* | pile seaperch | W, SP, S, F | C, P, J, AR | SF, CF, RT, PG&E, T, BS | 40.9 | R | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Embiotoca lateralis* | striped seaperch | SP, S, F, W | C, P, J | SF, CF, RT, PG&E, T, BS | 31.0 | | Ranked fourth in surfperch sport catch during 1957–1960 survey (Miller and Gotshall 1965). |
| *Hyperprosopon anale* | spotfin surfperch | * | AR | Scuba | | OV | *One occurrence observed by scuba diver at artificial reef (Prince 1972). |
| *Hyperprosopon argenteum* | walleye surfperch | SP, S, F, W | C, P, J, AR | SF, CF, RT, PG&E, T | | R | Most abundant surfperch in Bay sport fish catch during 1957–1960 survey (Miller and Gotshall 1965). |
| *Hyperprosopon ellipticum* | silver surfperch | SP, S, F, W | C, P, J | SF, CF, RT, PG&E, BS | 18.8 | S | Capture of juveniles indicates that spawning takes place in Bay. |
| *Phanerodon furcatus* | white seaperch | SP, S, F, W | C, P, J, AR | SF, CF, RT | 33.8* | S | * New size record; previous record was 31.5 cm (Miller and Lea 1976). |
| Family Engraulidae | | | | | | | |
| *Engraulis mordax* | northern anchovy | SP, S, F, W* | C, P, J | LF, SF, CF, RT, PG&E, BS | 14.0 | R | * Larvae captured during March, August, September, and December (Eldridge and Bryan 1972). Important food for chinook and coho salmon. Probable resident of Bay. |
| Family Gadidae | | | | | | | |
| *Microgadus proximus* | Pacific tomcod | SP, S, F, W | C, J | RT, PG&E | 27.7 | F | |
| Family Gasterosteidae | | | | | | | |
| *Aulorhynchus flavidus* | tubesnout | W, SP | C, MF | RT, PG&E | 11.5 | R | |
| *Gasterosteus aculeatus* | threespine stickleback | SP, S, F, W | C | RT, PG&E | 8.5 | R | |
| Family Gobiidae | | | | | | | |
| *Clevelandia ios* | arrow goby | S, F, W | C, MF | LF, BS | 5.6* | R | *New size record; previous size record was 5.1 cm (Miller and Lea 1976). |
| *Coryphopterus nicholsi* | blackeye goby | SP, F | C | RT | | R | |
| *Eucyclogobius newberryi* | tidewater goby | W, SP* | C, MF | LF, BS | 4.6 | R | * Juveniles captured in November (Eldridge and Bryan 1972); probable resident. |
| *Lepidogobius lepidus* | bay goby | W, SP, S, F* | C | LF, RT, PG&E | 13.0** | R | * Juveniles captured in January, February, April, and May (Eldridge and Bryan 1972). Probably resident. ** New size record, previous record was 10.2 cm (Miller and Lea 1976). |

**APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]—Continued**

| *Species* | *Common name* | *Season of occurrence*[2] | *Habitat*[3] | *Capture method*[4] | *Bay maximum size (cm)* | *Bay function*[5] | *Remarks* |
|---|---|---|---|---|---|---|---|
| Family Gonostomatidae | | | | | | | |
| *Cyclothone acclinidens* | benttooth bristlemouth | | C | LF* | 0.4 | OV | * Oceanic species, occasionally enters Bay channels, probably during very high tides. |
| Family Hexagrammidae | | | | | | | |
| *Hexagrammos decagrammus* | kelp greenling | SP, S, F, W | C, MF, P, J, AR | LF*, SF, RT, PG&E, T | 33.5 | S | * 0.8-cm larvae collected in February (Eldridge and Bryan 1972). Ranked fifth in 1957–1960 survey of Bay sport fishing (Miller and Gotshall 1965). |
| *Hexagrammos superciliosus* | rock greenling | S, F | C, J | SF, RT | 24.0 | R | Minor component of catch of jetty sport fishermen. |
| *Ophiodon elongatus* | lingcod | SP, S, F, W * | C, MF, J, AR | LF, SF, RT, PG&E | ** | F, N | * Larvae were captured during January and February (Eldridge and Bryan 1972). Juveniles occur in channels and in tide flats during spring and summer. Minor component of Bay sport catch in terms of numbers, but major when size and popularity are considered. ** The largest lingcod recorded from Bay reportedly weighed in excess of 18.1 kg. |
| *Oxylebius pictus* | painted greenling | | C, J | SF * | | R | * Commonly observed by divers around jetties. |
| Family Liparididae | | | | | | | |
| *Liparis fucensis* | slipskin snailfish | W, S | C, MF | RT | 10.0 | R | |
| *Liparis pulchellus* | showy snailfish | W, SP, S, F | C, MF | RT | 16.0 | R | |
| *Liparis rutteri* | ringtail snailfish | * | J | SF | | OV | * Only one record; caught by a sport fisherman at the Buhne Pt. jetty in 1957. |
| Family Luvaridae | | | | | | | |
| *Luvarus imperialis* | louvar | * | oceanic | hand | 66.4 | OV | * One record from Bay; found floating half dead near a log raft off Eureka (Gotshall and Fitch 1968). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Family Molidae | | | | | | | |
| *Mola mola* | ocean sunfish | * | oceanic | observed on surface | — | OV | * One common mola was observed in the PG&E intake canal in September 1970. |
| Family Myctophidae | | | | | | | |
| *Stenobrachius leucopsarus* | northern lampfish | W, SP * | C, oceanic | LF | 0.5 | OV | * Larvae collected in January, March, and May represent the only Humboldt Bay records (Eldridge and Bryan 1972). These oceanic fish probably came into the Bay during very high tides. |
| *Tarletonbeania crenularis* | blue lanternfish | | C, oceanic | LF * | 0.7 | OV | * The only records for Humboldt Bay were from Eldridge and Bryan's (1972) larval fish study. |
| Family Ophichthidae | | | | | | | |
| *Ophichthus zophochir* | yellow snake eel | * | C | PG&E | | OV | * One record from Bay collected at PG&E screens in January 1971 (Quirollo and Dinnel 1975). |
| Family Ophidiidae | | | | | | | |
| *Chilara taylori* | spotted cusk-eel | W, S | C, MF | RT | 27.5 | R | |
| Family Osmeridae | | | | | | | |
| *Allosmerus elongatus* | whitebait smelt | F, W, S | C | RT | 11.0 | F | |
| *Hypomesus pretiosus* | surf smelt | SP, S, F, W | C | LF, PG&E | 18.0 | F | |
| *Spirinchus starksi* | night smelt | W, SP, S, F | C | LF, RT | 13.0 | F | |
| *Spirinchus thaleichthys* | longfin smelt | F, W, SP | C | LF, RT, PG&E | 15.0 | F | |
| *Thaleichthys pacificus* | eulachon | W | C | RT | 19.0 | OV | |
| Family Percichthyidae | | | | | | | |
| *Morone saxatilis* | striped bass | * | C | SF | 27 kg | OV | * One questionable record from Bay; a fish reported caught over 90 years ago. D.L. Wainwright, Humboldt St. Univ., unpubl. data. |
| *Sterolepis gigas* | giant sea bass | * | C | SF | 7 kg | OV | * One record from Bay (Boydstun 1967). |
| Family Pholidae | | | | | | | |
| *Apodichthys flavidus* | penpoint gunnel | F | C, MF | RT, BS | 10.6 | R | |
| *Pholis ornata* | saddleback gunnel | SP, S, F, W | C, MF, J | RT, PG&E, BS | 19.4 | R | |

**APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]—Continued**

| *Species* | *Common name* | *Season of occurrence* [2] | *Habitat* [3] | *Capture method* [4] | *Bay maximum size (cm)* | *Bay function* [5] | *Remarks* |
|---|---|---|---|---|---|---|---|
| Family Pleuronectidae | | | | | | | |
| *Isopsetta isolepis* | butter sole | W, S | C | RT | 13.1 | F | |
| *Microstomus pacificus* | dover sole | * | C | RT | 9.2 | OV | * Three specimens collected in 1968. A very important commercial trawl species outside of Bay. |
| *Parophrys vetulus* | English sole | SP, S, F, W | C, MF | LF *, RT, PG&E, T, BS | 20.0 | N | * Juveniles are very abundant in Bay. English sole were one of the most abundant fishes in the research trawls. Because of the large numbers the Bay should be considered as a nursery area. A very important component of commercial trawl catches outside of Bay. |
| *Platichthys stellatus* | starry flounder | SP, S, F, W * | C, J | LF, SF, RT, PG&E | 56.0 | R | * Larvae from 0.5 to 0.9 cm collected from June through August (Eldridge and Bryan 1972). Juveniles and adults may move out of Bay for short periods, but starry flounders should be considered residents. |
| *Pleuronichthys coenosus* | C-O sole | | C | RT | | OV | * Juvenile collected in January (Eldridge and Bryan 1972). |
| *Pleuronichthys decurrens* | curlfin sole | SP, S, F, W | C | RT | 14.0 | N | |
| *Psettichthys melanostictus* | sand sole | SP, S, F, W | C, J | LF *, SF, RT, PG&E | 27.0 | N | * Juvenile collected in January (Eldridge and Bryan 1972). |
| Family Salmonidae | | | | | | | |
| *Oncorhynchus kisutch* | coho salmon | SP, S, F, W | C, J | SF *, RT, PG&E, BS | | F, N, M | * One of the most important sport fish to enter the Bay. Adults present in summer to feed and fall on spawning migration to enter Bay tributaries. Juveniles spend at least part of their first year of life in Bay. |
| *Oncorhynchus tshawytscha* | chinook salmon | SP, S, F, W | C, J | SF *, PG&E, BS | | F, N, M | * Same as coho salmon. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Salmo clarki* | cutthroat trout | * | C | SF | | F | * Rarely enters Bay; usually taken by youngsters fishing at the mouths of tributary streams. Formerly very abundant as the "speckled trout" taken by early residents. The sea-run form has been severely depressed by reclamation of the Bay with dikes that have "flap gates" on entrances of small tributaries. |
| *Salmo gairdneri* | rainbow trout | F * | C | SF | | M | * Rarely enter ocean or Bay sport fishery. A few are caught near mouths of tributary streams. |
| Family Sciaenidae | | | | | | | |
| *Cynoscion nobilis* | white seabass | W* | C | LF | 0.6 | OV | * Larvae collected during December and January (Eldridge and Bryan 1972). |
| *Genyonemus lineatus* | white croaker | S, F | C, J | SF | | F | |
| Family Scorpaenidae | | | | | | | |
| *Sebastes auriculatus* | brown rockfish | SP, S, F, W | C, P, AR | RT, PG&E, T, Scuba | 30.0* | R | * (Prince 1972). Juveniles appear to have become resident at an artificial reef on Southport channel. |
| *Sebastes caurinus* | copper rockfish | SP, S, F, W | C, P, J, AR | SF, RT, PG&E, T | 34.0 * | R | * (Prince 1972). |
| *Sebastes flavidus* | yellowtail rockfish | * | C | PG&E | | OV | * One juvenile from PG&E screens. (P. Dinnel, pers. commun.). |
| *Sebastes melanops* | black rockfish | SP, S, F, W | C, P, J, AR | SF, RT, PG&E, T | 60.3 * | R | * Caught by a sport fisherman. |
| *Sebastes miniatus* | vermilion rockfish | * | C | PG&E | 15.0 | OV | * One record at PG&E screens (P. Dinnel, pers. commun.). |
| *Sebastes mystinus* | blue rockfish | S, F, W * | C, J, AR | SF | | F | * (Prince 1972). |
| *Sebastes paucispinis* | bocaccio | S, F, W | C | RT, PG&E | | F | |
| *Sebastes rastrelliger* | grass rockfish | W, SP | C, P, J | SF, RT, PG&E, T | 36.0 | R | |

**APPENDIX 1. Annotated List of Fishes from Humboldt Bay, California[1]—Continued**

| *Species* | *Common name* | *Season of occurrence* [2] | *Habitat* [3] | *Capture method* [4] | *Bay maximum size (cm)* | *Bay function* [5] | *Remarks* |
|---|---|---|---|---|---|---|---|
| Family Stichaeidae | | | | | | | |
| *Anoplarchus purpurescens* | high cockscomb | SP | C | RT | | R | |
| *Cebidichthys violaceus* | monkeyface prickleback | * | C, J | SF, RT | | R | * Reported occurences at the jetties have not be verified. |
| *Chirolophis decoratus* | decorated warbonnet | * | J | SF | 25.8 (SL) | OV | * One record (Behrstock 1976). |
| *Lumpenus sagitta* | snake prickleback | SP, S | C | RT, PG&E | 31.6 | R | |
| Family Stromateidae | | | | | | | |
| *Peprilus simillimus* | Pacific pompano | | C | PG&E | 15.0 | OV | |
| Family Syngnathidae | | | | | | | |
| *Syngnathus leptorhynchus* | bay pipefish | SP, S, F, W | C, MF | RT, PG&E | 34.8* | R | * New size record; previous record 33.0 cm (Miller and Lea 1976). |
| Family Trachipteridae | | | | | | | |
| *Trachipterus altivelis* | king-of-the-salmon | * | C | Scuba | | OV | * One record (J. Houck, pers. commun.). |
| Family Trichodontidae | | | | | | | |
| *Trichodon trichodon* | Pacific sandfish | * | C | SF | | OV | * One record from Bay (L. B. Boydstun, pers. commun.). |

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# FOOD HABITS OF PINTAILS, *ANAS ACUTA*, WINTERING ON SEASONALLY FLOODED WETLANDS IN THE NORTHERN SAN JOAQUIN VALLEY, CALIFORNIA [1]

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**Esophagi of 109 Pintails, *Anas acuta*, collected from September 1976 through February 1977 at the Los Banos Wildlife Area, California, were examined for plant and animal contents. Aggregate volume percentage of animal food items were: September, 1%; October, 5%; November, 81%; December, 60%; January, 85%; and February, 65%. Adult insects of the family Chironomidae made up most of the animal portion of the diet. Swamp timothy, *Heleochloa schoenoides*, and wild millet, *Echinochloa crusgalli*, were the most common vegetative food items. Animal material constituted a much higher percentage of the diet of nonbreeding Pintails, than was previously reported. Research into techniques to estimate invertebrate biomass in specific vegetative types is needed to evaluate the aspects of preference versus availability in nonbreeding-season foods of Pintails.**

## INTRODUCTION

Waterfowl have been observed actively feeding in marsh areas which appear to be devoid of any vegetative matter; the logical question is: what are they feeding on? Nonbreeding ducks have been regarded as primarily vegetarians (Kortright 1942, McGilvrey 1966, McMahan 1970). However, Swanson and Bartonek (1970) have demonstrated that analyses of gizzard contents inflate the importance of seeds in the diet of ducks. Past studies of waterfowl food habits that were based on gizzard contents may have eclipsed the importance of readily digested animal material in the birds' diet. Analyses of esophageal contents soon after birds have fed more accurately reflect the diet of waterfowl (Swanson and Bartonek 1970).

Studies of the importance of invertebrates in the diets of ducks have dealt primarily with pre-breeding and breeding birds (Swanson, Meyer, and Serie 1974; Krapu 1974; Serie and Swanson 1976; Krapu and Swanson 1977). The purpose of our study was to determine the importance of invertebrates in the diets of nonbreeding Pintails, based on esophageal examination. The information is needed for developing management strategies to encourage waterfowl use on the Los Banos Wildlife Area and, hopefully, other marsh lands.

## STUDY AREA

Los Banos Wildlife Area is located 4 km northeast of the town of Los Banos, Merced County, California. The area encompasses 1094 ha of seasonally flooded wetlands. Major species of marsh plants include jointgrass, *Paspalum distichum;*

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wild millet; alkali bulrush, *Scirpus robustus;* sprangetop, *Leptochloa fascicularis;* swamp timothy; and cattail, *Typha latifolia.* Water depth in the area does not exceed 60 cm. The average water depth after flooding in September is 30 cm. This depth is maintained until February when drainage and evaporation begin gradually lowering the ponds to a mudflat stage, and they finally dry up near the early part of May.

## METHODS

Collections were made from 1 September 1976 through 29 February 1977. Pintails observed feeding for 15–20 minutes were shot. Esophageal contents were then removed within 5 minutes after the birds were killed and preserved in 80% ethyl alcohol to prevent post-mortem digestion (Swanson and Bartonek 1970). Food items were identified and their volume determined by water displacement in graduated cylinders. Data were summarized as aggregate volume (Martin, Gensch, and Brown 1946) and frequency of food items in samples. Only food items that achieved a volume of 0.1 cc or more were used to compute aggregate volume. Volumes of less than 0.1 cc were recorded as trace items and used in the frequency of occurrence tabulation.

## RESULTS AND DISCUSSION

Chironomid adults and pupal cases contributed most of the animal portion of the diet. Swamp timothy and wild millet dominated the vegetative portion of the diet. The ratio of animal matter to vegetation varied considerably between months (Table 1). Birds collected in September and October had less than 5% invertebrate material in esophagi. Those shot from November to February contained invertebrate volumes greater than 60% and as high as 85% of the monthly diet. More animal than vegetative material was eaten from November through February. These data show that invertebrates are much more important in the winter diet of Pintails than has been reported previously by Kortright (1942), Martin et al. (1951), and Anderson (1959).

Invertebrate populations may take from 1 to 2 months after flooding to become available in a seasonal marsh, which in part may explain the November increase in invertebrate use. Flooding of marsh fields on the study area occurred in September 1976.

Although there was no statistically significant difference in invertebrate use between age and sex classes of Pintails, males used more invertebrate materials from November through February than did the females (Figure 1). Differences in invertebrate intake between males and females may reflect seasonal differences in metabolic demands. There was a positive correlation (Spearman's *rho* .753; $n = 19$; $p < .01$) between aggregate volume and frequency of food items in samples.

High invertebrate usage by waterfowl in wintering habitats indicates the need for wetland managers to develop habitats that will nurture desirable invertebrate populations. Prostrate, dense vegetation and their roots may be more advantageous in producing invertebrate than plants that provide little in the way of submerged vegetation. Studies in New York State (Krull 1970) have found direct correlation between macroinvertebrate abundance and amount of submerged aquatic vegetation. Also, water level control may be critical to insure that areas

**TABLE 1. Major Food Items of 109 Pintails collected September through February on the Los Banos Wildlife Area in the Central Valley of California, 1976–77.**

| *Food items* | Aggregate volume (%) | | | | | | Frequency of food item in sample (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Sept.* | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Sept.* | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* |
| *Sample Size* | *7* | *14* | *9* | *13* | *23* | *43* | *7* | *14* | *9* | *13* | *23* | *43* |
| PLANT | | | | | | | | | | | | |
| *Heleochloa schoenoides* | 6 | 89 | 3 | – | – | 5 | 57 | 64 | 44 | 15 | 4 | 21 |
| *Echinochloa crusgalli* | 91 | 4 | 8 | 32 | 2 | 5 | 86 | 50 | 78 | 77 | 61 | 49 |
| *Scirpus robustus* | 2 | 2 | – | 5 | 9 | 6 | 14 | 43 | 11 | 23 | 22 | 28 |
| *Polygonum lapthifolium* | – | – | – | 3 | – | – | 14 | 21 | 11 | 38 | 30 | 23 |
| *Rumex crispus* | – | – | – | – | – | 1 | 14 | 50 | 22 | 8 | – | 14 |
| Forb stem fragments | – | – | – | – | 2 | 9 | 14 | - | – | – | 13 | 9 |
| *Panicum* | – | – | 8 | – | 2 | 3 | 14 | 21 | 44 | 38 | 22 | 35 |
| Plant fragments | – | – | – | – | – | 5 | – | 7 | – | – | 13 | 33 |
| *Cyperus* | – | – | – | – | – | – | – | 7 | – | – | – | – |
| TOTAL PLANT | 99 | 95 | 19 | 40 | 15 | 34 | | | | | | |
| ANIMAL | | | | | | | | | | | | |
| Larva fragments | 1 | – | – | – | – | – | 29 | – | – | – | – | – |
| Insect fragments | – | 4 | 11 | 19 | 13 | 11 | 57 | 71 | 44 | 61 | 39 | 25 |
| Dytiscidae | – | – | – | – | – | – | – | 7 | – | 8 | 4 | 14 |
| Chironomidae larvae | – | 1 | 70 | 41 | 52 | 32 | – | 14 | 78 | 100 | 74 | 88 |
| Chironomidae pupal cases | – | – | – | – | – | 4 | – | – | – | – | 4 | 9 |
| Crustacean fragments | – | – | – | – | 13 | – | – | – | – | – | – | – |
| Molluska | – | – | – | – | – | 5 | – | – | – | – | – | 5 |
| Hydrophilidae larvae | – | – | – | – | – | 5 | – | – | – | – | – | 2 |
| *Eucrypsis* and *Daphnia* | – | – | – | – | 7 | 7 | – | – | 11 | 46 | 43 | 47 |
| Odonata nymph | – | – | – | – | – | 1 | – | – | 11 | 46 | 43 | 2 |
| TOTAL ANIMAL | 1 | 5 | 81 | 60 | 85 | 65 | | | | | | |

having available invertebrate populations are not raised to a level that discourages use by waterfowl.

Research into techniques to estimate invertebrate biomass in specific vegetative types is needed to evaluate the aspects of preference versus availability in winter foods of Pintails.

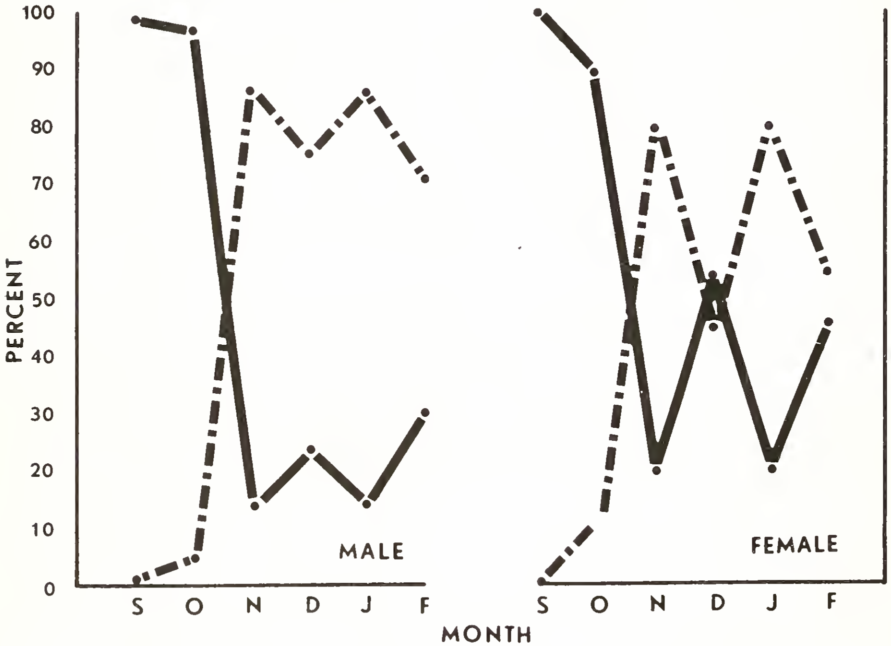


FIGURE 1. Monthly aggregate volume percentage of animal and vegetative food items found in the esophagi of male and female Pintails collected at the Los Banos Wildlife Management Area, California, 1976–77. Solid line—vegetation; Broken line—animal

## ACKNOWLEDGMENTS

Appreciation is extended to the following California Department of Fish and Game personnel: J. Cawthon provided the original impetus for the project; D. Ruegg and C. Wood helped in the collection, preparation, and analysis of samples. We are also indebted to W. Stienecker, formerly with the Food Habits Section of the Department's Field Laboratory, for his assistance and use of laboratory facilities. R. McLandress, University of California, Davis, reviewed the manuscript and provided valuable suggestions for its improvement.

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# NOTES

## HARBOR SEAL AND FISH POPULATIONS—BEFORE AND AFTER A SEWAGE SPILL IN SOUTH SAN FRANCISCO BAY

A sewage spill occurred 4 through 29 September 1979, at the San Jose-Santa Clara Water Pollution Control Plant during which 4,000,000,000 gallons of partially treated sewage flowed into Artesian Slough (H. Singer, Senior W.R.C.E., California Regional Water Quality Control Board, pers. commun.). Initial reports by the media indicated massive wildlife die-offs in the Bay south of the Dumbarton Bridge.

It does not appear that effluent reached Mowry Slough, which is a major harbor seal haul-out area in San Francisco Bay (Fancher 1979; Risebrough et al. 1979) about 8 miles from the spill's origin (Figure 1). Data on fish and seal numbers in the Mowry Slough area are available before, during, and after the spill as part of a year-long harbor seal study on the San Francisco Bay National Wildlife Refuge. Although sample size is small, the results are of interest since the impact of the spill on south Bay macrofauna is still unknown.

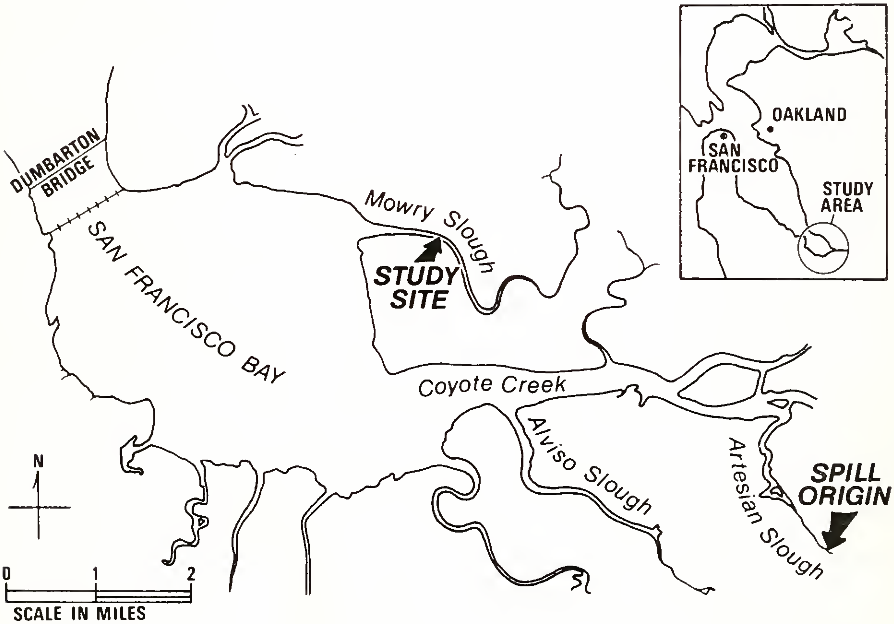


FIGURE 1. Map of San Francisco Bay showing where the sewage spill originated and the Mowry Slough study site.

Fish were sampled with a specially designed trap (Wild 1969) of 6-mm square mesh set at high tide to completely block a 5-m wide, 2-m deep tidal gut. Fish present in the gut were trapped as the water drained with the receding tide, a process taking approximately 4 hours. There were no major differences between sampling results 7 days prior to spillage onset, during the spill, and 5 days after the spill ceased (Table 1). The increased numbers of northern anchovy, *Engrau-*

*lis mordax,* and bay shrimp, *Crangon franciscorum,* appear minor when compared to the monthly fluctuations seen in the south Bay by Alpin (1967) and Wild (1969), respectively. Dead or deformed fish were not observed during this study.

**TABLE 1. Numbers of Fish and Invertebrates Collected at Mowry Slough Before, During, and After a September 1979 Sewage Spill.**

| | Date: | August 28 | September 6 | October 4 |
|---|---|---|---|---|
| | Time trap set: | 0530 | 1430 | 1335 |
| | Salinity: | 25.5 ‰ | 26.0 ‰ | 26.0 ‰ |
| | Temperature water: | 20° C | 24° C | 21° C |
| *Species* | | *Number of Individuals* | | |
| **Fish** | | | | |
| Topsmelt *Atherinops affinis* | | 235 | 309 | 237 |
| Northern anchovy *Engraulis mordax* | | 2 | 38 | 94 |
| Yellowfin goby *Acanthogobius flavimanus* | | 3 | 7 | 1 |
| Threespine stickleback *Gasterosteus aculeatus* | | 4 | 4 | 1 |
| Dwarf perch *Micrometrus minimus* | | 0 | 1 | 8 |
| Shiner perch *Cymatogaster aggregata* | | 1 | 0 | 0 |
| Rainwater killifish *Lucania parva* | | 0 | 0 | 2 |
| Pacific staghorn sculpin *Leptocottus armatus* | | 8 | 0 | 0 |
| Leopard shark *Triakis semifasciata* | | 0 | 2 | 3 |
| | | 253 | 361 | 346 |
| **Invertebrates** | | | | |
| Mud crab *Hemigrapsus oregonensis* | | 0 | 6 | 1 |
| Oriental shrimp *Palaemon macrodactylus* | | 5 | 0 | 20 |
| Bay shrimp *Crangon franciscorum* | | 35 | 50 | 172 |
| | | 40 | 56 | 193 |

Harbor seals, *Phoca vitulina richardii,* were counted two to seven times per month at Mowry Slough during 1979. Twenty-five seals were hauled-out on the last census made prior to the spill. The number of seals fluctuated between 17 and 35 during and immediately after the spill (Table 2). Based on past censusing (Fancher 1979), a fluctuating seal count of this magnitude is not unusual for the fall and winter months at Mowry Slough.

A dead seal found at Mowry Slough on 27 September 1979, 23 days after the spill began, was unusually small, indicating a chronic condition probably not attributable to the recent spill. Although the last known pupping in the area occurred in May, this small seal (8.7 kg, 86.9 cm TL) with adult pelage was similar in size to a newborn pup. It was retained at the Museum of Vertebrate Zoology, U.C. Berkeley, for additional study.

**TABLE 2. Harbor Seal Numbers at Mowry Slough Before, During, and After the Spill. Counts Were Made 2 to 5 Hours After High Tide**

| | *Date* | *Number of seals* |
|---|---|---|
| | 30 August | 25 |
| Spill started: | 4 September | |
| | 14 September | 25 |
| | 25 September | 17* |
| | 27 September | 27 |
| | 29 September | 20 |
| Spill stopped: | 30 September | |
| | 2 October | 35 |
| | 11 October | 24 |
| | 16 October | 32 |
| | 30 October | 33** |
| | 31 October | 35 |

* At low tide.
** Two hours after low tide.

Based on the above, obvious short-term effects of the sewage spill on Mowry Slough seal and fish populations appear to be minimal or absent. Long-term effects are possible and monthly monitoring of both seal and fish populations continues.

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# STATUS OF REDEYE BASS, *MICROPTERUS COOSAE,* IN THE SOUTH FORK STANISLAUS RIVER, CALIFORNIA

Redeye bass, *Micropterus coosae,* are native to streams in the lower Appalachian regions of Alabama, Tennessee, Florida, Georgia, North Carolina, and South Carolina (MacCrimmon and Robbins 1975). They are most common in small headwater streams (Hurst, Bass, and Hubbs 1975). Ramsey (1975) asserts that redeye bass are similar to smallmouth bass, *M. dolomieui,* in habitat requirements. According to Parsons (1954), redeye bass are the brook trout of the warmwater game fish because they are similar in size, habitat preference, feeding habits, desirability, and gameness.

In an effort to provide more diverse gamefish populations in California's small warmwater streams, the California Department of Fish and Game transplanted redeye bass from Georgia and Tennessee to a total of six California streams from 1962 to 1964 (Goodson 1966). Included was the South Fork Stanislaus River

below Lyons Reservoir in Tuolumne County, which received 510 fingerlings in July 1962. The South Fork Stanislaus River, situated in the Sierra Nevada foothills, has widely varying flows. Flows of 28 m $^3$/s or greater are common during spring and early summer, but drop sharply to about 0.06–0.14 m $^3$/s in late summer and fall. Temperatures reach as high as 27.7°C in August.

To determine fish species composition in the South Fork Stanislaus River two 30-m sampling stations were electrofished on 25 October, 1978. One station was established immediately above the confluence of Fivemile Creek; the other was 8 km upstream near Keltz Mine. The stations were at elevations of 450 and 650 m, respectively.

The redeye bass was the dominant species captured; of 92 fish collected from both stations, 79 were redeye bass. Other fish included: California roach, *Hesperoleucus symmetricus;* hardhead, *Mylopharodon conocephalus;* Sacramento sucker, *Catostomus occidentalis;* and brown trout, *Salmo trutta.* Identification of the bass as *Micropterus coosae* was confirmed by T. Mills (Fishery Biologist, Dept. Fish and Game). Ten of the redeye bass were deposited in the Department's Ichthyological Museum.

Redeye bass collected were generally small. Sixty four of the 79 fish examined ranged from 30 to 53 mm fork length (FL); these were presumably young-of-the-year. The remaining 15 ranged from 100 to 191 mm FL (Figure 1).

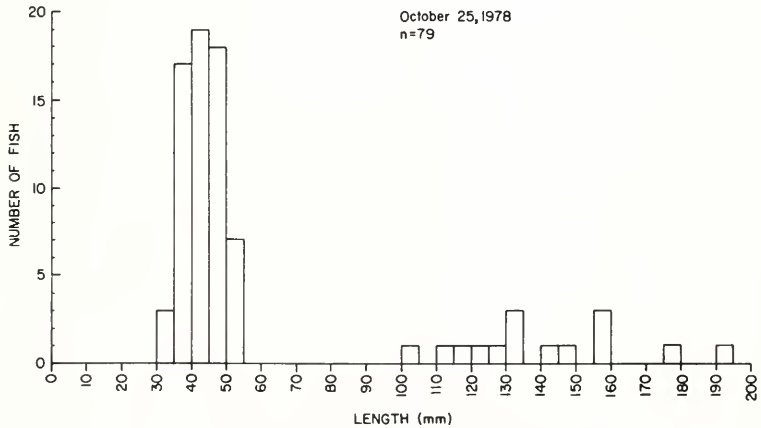


FIGURE 1. Redeye bass length frequency histogram, South Fork Stanislaus River

Redeye bass receive light fishing pressure in the South Fork Stanislaus River (J. Horton, Fishery Biologist, Dept. Fish and Game, per. commun.), apparently because of their comparative small size. Effects of the redeye population on other fish populations are unknown.

## ACKNOWLEDGMENTS

J. L. Horton (California Department of Fish and Game), R. E. Geary, and H. R. Landis (Pacific Gas and Electric Company) assisted in collecting the fish. I thank R. E. Geary and B. F. Waters (PG&E) for reviewing the manuscript.

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*Accepted for publication June 1980.*

## A GEOGRAPHIC RECORD FOR THE REDTAIL SURFPERCH, *AMPHISTICHUS RHODOTERUS*

This report presents a new geographic record for the Redtail surfperch, *Amphistichus rhodoterus.* Specimens are now deposited in the Ichthyology museum at the University of California, Davis, California (numbers 348-15-01 and 348-15-02).

Twenty-eight specimens of *Amphistichus rhodoterus* were captured in the surf zone of a sandy beach at Avila Beach, California, on 6 August 1977. They were taken using a 80 ft. beach seine. All of the fish examined were females, ranging in size from 73 to 76 mm (SL). An examination of several scales from each fish revealed no annulus formation, suggesting that these fish were young-of-the-year.

Hart (1973) indicates that this species occurs from Half Moon Bay, California to Vancouver Island, British Columbia. Miller and Lea (1972) report that *A. rhodoterus* occurs from Monterey Bay to Vancouver Island, British Columbia. Using the information presented by Miller and Lea (1972) our capture extends the southern geographic limit of this species by some 160 km.


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# BOOK REVIEWS

### Management of Semi-Arid Ecosystems

**Edited by Brian H. Walker; Elsevier Scientific Publishing Company, Amsterdam, The Netherlands; 1979; 398 pp; $78.00**

*Management of Semi-Arid Ecosystems* consists of summaries of papers by authors conducting research on and management of a number of selected semi-arid regions. The editor defines "semi-arid" as that portion of the earth's surface that experiences a climate which allows for the development of a more-or-less continuous vegetative cover, but which is too dry and variable to permit regular, successful, annual dry-land cultivation of cereal or other crops. Areas covered by chapters are southwestern USA, Mexico, Brazil, southern and eastern Africa, the southern Sahara, Israel, India, the USSR, central Asia, and Australia. Each chapter covers a general description of the environment, history of management practices, and recommendations. The book concludes with a discussion and general recommendations by the editor.

The purpose of the book is to analyze management principles which will promote sustained, optimum use and to identify common principles for land use in semi-arid ecosystems. Although the title implies the management of ecosystems, it is misleading, since it generally neglects the native fauna and flora. There are attempts to combine range and agriculture management with wildlife management, but usually wildlife is considered only to be of secondary value and then only where it is of commercial value. Fortunately, at least in part of the United States, "Public concern about aesthetics, habitat destruction, or the balance of nature has at times been great enough to halt range improvement projects". Since most of the range land in the United States is public land, it seems logical that native species and their habitat should finally be considered. I was pleased to see a general recommendation requirement for environmental or ecological impact assessments where large-scale developments are proposed.

Range managers will find this book a useful reference, as will the biologist, but for a different reason. The biologist can better deal with the problems resulting from the misuse of land when his knowledge includes what the user is trying to do and why.—James A. St. Amant

### Rare and Endangered Biota of Florida—Vol. I Mammals

**Edited by James N. Layne; University Presses of Florida, 15 N.W. 15th St. Gainesville, Florida 32603. 1979; 52 pp; illustrated; $5.00.**

My first impression of this technical volume, after glancing through it, was of a slick, professional, well-researched publication, not the usual sort of technical literature one sees on endangered species these days. After spending some time on the book, the impression was strengthened. This is a publication that, along with its existing companion volumes on birds (Vol. II), amphibians and reptiles (Vol. III), and fishes (Vol. IV), should serve as an example of how endangered species information may be presented. Three additional volumes in the series are yet to be published on plants, invertebrates, and recommendations and liaison.

This volume on Florida's endangered mammals treats 36 species or subspecies of land mammals (including the West Indian Manatee) in detail and 21 species of cetaceans in general. A discussion of recently extirpated and extinct mammals is also included. Each of the detailed accounts of the 36 land mammals covers description, other common names, range (including a range map), habitat, life history and ecology, specialized or unique characteristics (in many accounts), basis of status classification, recommendations, and selected references. The 36 mammals are classified as endangered (10 species), threatened (9), rare (11), species of special concern (1), and status undetermined (5). Evidently, only the endangered and threatened mammals receive protection under the Wildlife Code of the Florida Game and Fresh Water Fish Commission. It is a pleasure to see the terms "threatened" and "rare" used in the correct way—threatened to mean likely to become endangered if trends continue, and rare to mean low in numbers due to living only in a restricted area or sparsely distributed over a wide range. "Rare" has been used elsewhere incorrectly to indicate "threatened." A helpful section to readers in Florida as well as elsewhere is a detailed "Description of Major Terrestrial and Wetland Habitats of Florida," which describes 14 habitat types.

This volume, along with the others in the *Rare and Endangered Biota* series, is a product of many persons and organizations. The series editor is Dr. Peter C. H. Pritchard of the Florida Audubon Society, and the mammal volume editor is Dr. James N. Layne of the Archbold Biological Station and chairman of the Special Committee on Mammals, of the parent Florida Committee on Rare and Endangered Plants and Animals. The series was sponsored by the Florida Audubon Society and

Florida Defenders of the Environment. Publications funding was provided by the U.S. Fish and Wildlife Service, Florida Power and Light Company, and the Edward Ball Wildlife Foundation. No fewer than 18 authors contributed to the species accounts.

The book is a convenient 19.5 x 26.5 cm in size and is softbound with glossy covers. There are 11 photographs, including that of the Mangrove Fox Squirrel on the front cover. The latter photograph is the only color one and is indistinct on my copy, due to color plates not lined up in printing. The Florida range maps in the species accounts are adequate to illustrate the range of all but the most restricted of species, when the scale of the map doesn't allow a good representation of the small range.

This volume will be very useful to all those persons, professionals and layment alike, interested in Florida's endangered mammals. And it should be widely circulated to all states with endangered species programs, as an example of how diverse interests and needs may be met in a single technical publication.—John R. Gustafson

**Rare and Endangered Biota of Florida: Vol. II Birds**

**Edited by Herbert W. Kale II (Series editor, Peter C. H. Pritchard), University Presses of Florida, 15 N.W. 15th St., Gainesville, Florida 32603, 1979; 121 p., illustrated.**

During the past decade many states and federal agencies have published booklets on the status of threatened species in their regions. One of the finest contributions has been produced in the State of Florida. A seven-volume series on Florida's rare and endangered biota is the work of many biologists comprising the Florida Committee on Rare and Endangered Plants and Animals. The series is sponsored by Florida Audubon Society and Florida Defenders of the Environment and is published for the State of Florida Game and Fresh Water Fish Commission. Volume II reports on the status of 74 forms of birdlife, which are categorized as Endangered, Threatened, Rare, Species of Special Concern, Status Undetermined, Recently Extirpated, and Recently Extinct. The listing used by the Committee is cross-referenced to the official Federal and State classifications of these birds. The volume contains an introductory overview of the state's threatened birds, explaining that "The preservation of wildlife involves the preservation of suitable habitat". As in most areas of the world the majority of species are listed ". . . because of man's destruction or alteration of habitat or some critical factor in the environment of these species." In recognition of the importance of habitat, there is a description of each of 14 major terrestrial and wetland habitats in the state; special emphasis is placed on freshwater marshlands, which are particularly important to many listed species, such as the Everglade Kite, Wood Stork, and Limpkin. Species accounts contain the physical description, range, habitat, life history, and special characteristics of each of the 74 listed birds, as well as the basis for status classification and recommendations for research and protection. The volume is enhanced by black and white (and one color) photographs or line drawings of the Endangered and Threatened birds, and some of those in other classifications. The range of each bird is depicted on individual state maps.

This is a well-researched, attractive, and useful reference source for anyone with an interest in Florida's threatened birdlife. Also, it should serve as a good example for similar conservation education efforts in other states.—*Ronald M. Jurek*

**Rare and Endangered Biota of Florida—Vol. III Amphibians and Reptiles**

**Edited by Peter C. J. Pritchard; University Presses of Florida, 15 N.W. 15th St., Gainesville, Florida 32603. 1979; 74 pp; illustrated; $5.50.**

**Rare and Endangered Biota of Florida—Vol. IV Fishes**

**Edited by Peter C. J. Pritchard; University Presses of Florida, 15 N.W. 15th St., Gainesville, Florida 32603. 1979; 58 pp; illustrated; $5.00.**

Quality; professional; slick; are a few of the adjectives that will come to mind when you first thumb through these two volumes on Florida rare and endangered fauna. Mindful of the old saw that you can't judge a book by its cover, I was anxious to find out if my first impressions were justified. I am happy to report that, in this case, they were.

Having some familiarity with publications of this kind, I know how difficult it is for a state agency to prepare and publish compendia on endangered species. Left to their own resources, it is rare for a product of this caliber to result. But by combining the direction and expertise of the scientific community, the organization and support of conservation groups, and supplemental funding from private industry, it has been possible for the Florida Game and Freshwater Fish Commission to publish these commendable third and fourth volumes in what will ultimately be an eight volume series on the rare and endangered vertebrates, invertebrates, and plants of Florida.

The production of the entire series is being directed by a 15-member Florida Committee on Rare and Endangered Plants and Animals, eight of whose members separately chair special (sub) committees dealing with mammals, birds, amphibians and reptiles, fishes, aquatic invertebrates, terrestrial invertebrates, and plants. A "recommendations and liaison" committee is the eighth. Each special committee is composed of most of the Florida academic and professional experts on the various taxa treated in each volume. The majority of the special committee members also are the authors of the individual species accounts. This arrangement helps assure the accuracy and completeness of the information presented and contributes to the overall professional quality of the volumes.

While there are slight differences between volumes three and four, the format of both is basically the same. The majority of the volumes is taken up by individual species accounts for 45 amphibians and reptiles and 43 fishes assigned to one of five status categories. Each species account lists the scientific and common name(s), and the family and order in which the species is classified. This is followed by sections which describe the species and summarize its range, habitat, life history and ecology, and any specialized or unique characteristics. There are also sections containing management recommendations, selected references, and an explanation for the basis of classifying the species as either endangered, threatened, rare, of special concern, or status undetermined.

I found the definitions of these status categories to be workable and biologically realistic, accommodating the various circumstances in which we find species in nature. Unlike California, where the rare designation includes both rare and threatened species, each category stands alone, as it should, with both the threatened and endangered definitions paralleling those of the 1973 Endangered Species Act. However, I disagree with the "fishes committee" decision to list as threatened rather than endangered those species in danger of being extirpated from the State of Florida but not endangered throughout their entire range. This appears to be a departure from the practice of other committees, and other states as well.

There are onlv two other major sections, in addition to the species accounts, in each volume. There is an introduction and a section describing the major habitats of Florida in which are found the amphibians and reptiles, and fishes, respectively. I found this section in both volumes to be most informative, but in Volume IV (Fishes) I had considerable difficulty relating the habitat descriptions in the species accounts to the nine major aquatic ecosystems described. Not so in Volume III, where such comparisons were facilitated by the Introduction itself, which was given primarily to an analysis of the distribution of the listed reptiles and amphibians in relation to the 14 major terrestrial and wetland habitat types in Florida. The author's analysis, of course, proceeded to the inevitable and universal conclusion that for nearly all "stressed" species, habitat preservation is the key to survival.

The Introduction of Volume IV takes a completely different tack, going to great lengths to explain how and why various fishes were or were not selected for listing. For those readers familiar with Florida's fishes I'm sure this approach was beneficial, and in my opinion it would have been helpful if something similar had been done by the authors of Volume III.

However, I found myself questioning some of the decisions and explanations discussed in the Introduction of Volume IV. I have already mentioned my disagreement with the decision to list as "threatened" those species endangered in Florida but not endangered throughout their range. Another decision to list two species as threatened for which there exists commercial or sport fisheries, was termed by the volume's editor (and committee chairman) as "apparent inconsistency". What is inconsistent, however, is the explanation: "so long as the habitat remains healthy, the animal will take care of itself"; that is, there will be surplus fish available for harvest.

Assuming that there is a common understanding as to what constitutes "healthy" habitat this axiom may generally be regarded as true. But implying that a threatened species exists in a healthy habitat is contrary to what one intuitively (and from experience) regards as the primary contributor to a species' threatened status; that is, "unhealthy" habitat. If, indeed, the habitat of the Atlantic sturgeon, *Acipenser oxyrhynchus*, is healthy, then what besides commercial fishing has caused the species to become threatened; that is, "likely to become endangered in the State within the forseeable [sic] future if current trends continue"? Judging from the species account, I would conclude that probably the Atlantic sturgeon in Florida should have been classified not as threatened, but as rare: "Species which, although not presently endangered or threatened . . ., are potentially at risk because they are found only within a restricted geographic area or habitat in the State . . .".

The shoal bass, *Micropterus* sp., on the other hand, seems to warrant its threatened classification, based on the information provided in the species account. But, if a truly threatened species is to be subject to fishing, managers must exercise caution in determining how much fishing mortality to allow a species to endure. Certainly there may be populations capable of withstanding some fishing mortality if the habitat of the particular population is in good condition, but if any fishing mortality is allowed on populations under stress in degraded or deteriorating habitats, there is the risk of

subjecting a species to further jeopardy by putting it at a disadvantage with its natural or (more likely) introduced competitors and predators.

Finally, it was interesting to note that the committee on fishes regarded species in large bodies of water, which are "most subject to the adverse affects of pollution, dredging or dam construction", to be more vulnerable to extinction than those ". . . in small bodies of water, which are, on the average, less likely to be subject to ecological perturbations than larger bodies of water." While such simple generalizations are not without risk, again they are also intuitively contrary to what one would expect, and they are in fact the opposite of what our experience in California has been. A large river may certainly be subjected to a variety of environmental abuses, but seldom does it relinquish its ability to support native species without a prolonged struggle. If fisheries managers can intervene early enough, the inevitable can be forstalled. But small bodies of water, such as desert springs, and small streams can be destroyed literally overnight by applied technologies within the means of any private landowner, and usually beyond the scrutiny of state or federal wildlife management agencies.

While I may have some minor quarrels with some of the material in the early chapters, the heart of the books, the species accounts themselves, are responsible for my largely favorable impressions. They are comprehensive, detailed, and most importantly, informative. Technical, biological, and ecological material is presented so as to be useful to biologists and resource managers, and is understandable by the average lay reader. Consequently, all concerned parties, perhaps even those with the capability to do something to help protect Florida threatened and endangered species, will hopefully understand and respond. After all, this is the ultimate purpose of publications of this kind.—*Steve Nicola*

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## AUTHORS

## SCIENTIFIC NAMES

## SUBJECT

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